HEATING OF METALS AND ALLOYS IN ELECTROLYTES

By

I.Z. Yasnogorodskiy

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TABLE OF CONTENTS

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Electrolytic Hardening - Heating of Metals and Alloys in Electrolytes

By

I.Z. Yasnogorodskiy

Stalin Prize Laureate

(Translated from the Russian into the German language by Fr. Krantz)

This book deals with the physical principles concerning the process of electrical heating of component parts with the help of electrolytes, the heating procedure, the construction of plants and installations, and the fields of application of the process.

The book is written for Industrial Heating Engineers and for Scientists.

Preface to Original Edition

This book describes the scientific bases and the utilization of a new process for the heating of metals and alloys in electrolytes. The process was developed by. I. Z. Yasnogorodski ... (Follow 6 pages of Soviet party propaganda.)

CHAPTER I

THE PHYSICAL PRINCIPLES GOVERNING ELECTRICAL HEATING IN AN ELECTROLYTE

An electrical current flowing through an electrolyte under certain specific conditions, disturbs the normal electrolysis; in such a case there will occur on one of the two electrodes a peculiar liminous manifestation, accompanied in certain types of electrolyes by an intensive heating of the electrode.

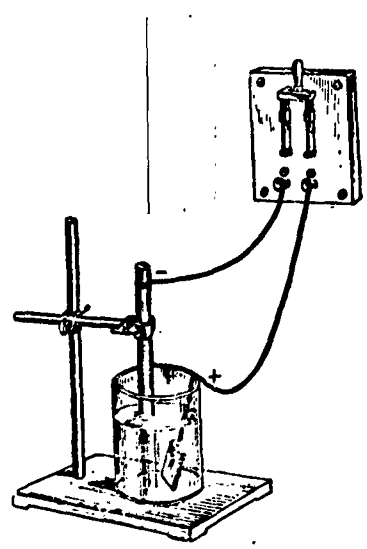


Figure 1. Test Arrangement

In the laboratory the heating effect of the electrode (cathode) can be demonstrated in the following manner. If an anode consisting of a metal plate and a cathode consisting of a metal rod are placed into a glass container filled with an electrolyte, one will observe at a voltage of 220V the above-mentioned luminescence between the immersed portion of the cathode and the electrolyte causing a heating of the immersed portion. The cathodic current density, of course, must be greater than the anodic current density. In the opinion of some research scientists this phenomenon is caused by the development of hydrogen at the cathode and oxygen at the anode resulting from a secondary effect of the current flowing through the electrolyte. The poor conductivity of the gas envelope forming at the cathode will produce with sufficiently high voltage a correspondingly high current and thus a large quantity of heat, heating the work piece (the cathode). If the direction of the current is reversed, the heating effect will cease; the envelope forming at the rod will then be composed primarily of oxygen. The author's own experiments permit an explanation of the processes occuring during the heating of a cathode in an electrolyte. The experiments revealed that the heat effect is also bound up with exothermic reactions within the gas envelope and possibly with atomic or molecular transmutations of the hydrogen.

a) Mechanics of the Process of Electrical Heating in an Electrolyte

The processes occurring at the cathode at higher voltages are based on general laws similar to those peculiar to a spheroid drop of a liquid.

If such a drop is placed upon the surface of a solid body immersed in a liquid and heated to a temperature considerably higher than the boiling point of the liquid, the drop will assume, without boiling, the shape of a flattened sphere, i. e. the shape of a spheroid.

The liquid evaporates rather slowly. If the surface of the solid body is thus cooled to a certain temperature the liquid will suddenly begin to boil

and spatters in all directions. The temperature of the solid body at which the spheroidally shaped droplet will be destroyed, is slightly above the boiling point of the liquid. The spheroid state is unstable; the spheroid is destroyed when the solid body has a very high temperature. At a certain surface temperature, therefore, a liquid put upon the surface of the solid body will not be able to wet (moisten + sprinkle) the body. The spheroid droplet is separated from the surface of the heated body by a layer of vapor which forms between them and is protected from the direct effect of the heat (Leidenfrost Phenomenon).

The following characteristic phenomena occur during the passage of current through such a system:

1. Under particularly favorable circumstances, e.g. if the surface of the solid body is smooth, clean, and uniformly heated, the spheroid obviously remains quite immobile; even at higher voltages there will be no passage of current from the solid body to the liquid.

2. If such favorable conditions are not given, the spheroid droplet will fall from time to time into an oscillating motion, and with sufficient cooling or with heating to higher temperatures, the current will eventually pass from the solid body to the liquid. In the spheroid state, the liquid sometimes breaks through the galvanic chain, it will sometimes also serve as a conductor and close the chain. When there is a passage of current, the pointer of the ammeter is deflected in irregular jerks; the spheroid is in a state of continuous oscillation. As the normal condition of the spheroid we must thus consider the state in which the (flow of) current is interrupted by the spheroid.

3. Roughness of the surfaces to be heated does not improve the regular flow of the process. With smooth surfaces, there were only a few rare and incidental contacts between spheroid and surface.

4. The space between spheroid and surface increases with increasing temperature up to a certain value (limit). Temperature increases beyond that limit do not lead to an increase of the intervening space; at very high temperatures the spheroid is less stable and will frequently start to oscillate. Thickness of the vapor layer between the droplet and the incandescent surface amounts to 0.003 - 0.16 mm when the spheroid is at reat.

The here cited characteristics may to a certain extent contribute to an explanation of the processes involved in the heating of a solid body in an electrolyte. They are, however, not sufficient to explain all of the observed phenomena. It will, for instance, be difficult to explain why there are certain solutions in which the luminescence at the cathode is not accompanied by a heating up of the cathode, and likewise, what causes the formation of a gas envelope at the cold electrode.

2. The Electrolytic Interrupter

To explain the physical actions occurring during the process of heating in an electrolyte, it will be necessary to recall to mind the essential mode of action of the electrolytic interrupter, e.g. for the purpose of an abrupt interruption of a high frequency current in the primary winding of an induction coil. The structure of an interrupter is very simple. Two electrodes with different surfaces are immersed into a glass container filled with an electrolyte. When current is applied, the above-mentioned light and heat phenomena occur at the electrode having the smaller surface. If the container is placed into the primary winding of an induction coil, it can serve as an interrupter. The end of a platinum wire, placed into a mercury-filled porcelain tube serves, as the active electrode. The following processes take place in such an interrupter: The passage of current causes the end of the platinum wire to glow, causing around the electrolyte the formation of a vapor envelope which insulates the electrode and interrupts the current.

The vapor envelope is immediately cooled by the liquid and condenses, the flow of current is resumed and the process is repeated. The correctness of this assumption is substantiated by the fact that there are no more interruptions when the temperature of the electrolyte reaches 90° C so that there is no longer any condensable vapor.

When the platinum wire was connected to the negative pole the spectroanalysis of the luminescent envelope at the cathode showed the lines of hydrogen and sodium and a number of other bright (light) lines. If the anode is the active electrode of the interruptor, there will be at the cathode a separation of hydrogen and at the anode a fairly explosive mixture composed of a small quantity of hydrogen and a large quantity of oxygen. With higher voltages, the hydrogen content of the gas mixture will increase, and the explosions will be more intensive. If the cathode is the active electrode, there will be at the anode a liberation of pure oxygen and at the anode a liberation of active hydrogen and only traces of oxyhydrogen gas. With a certain self induction and with a certain length of the platinum point, one may obtain up to 2000 interruptions per second.

a. Anodic Spark Discharge

Anodic spark discharge occurs only in a melted electrolyte and not in aqueous solutions. Anodic spark discharge occurs ar the surface of an anode immersed in a melted (liquid) electrolyte. This process is accompanied by a humming sound emerging from the induction coil. Anodic spark discharge may occur in any desired electrolyte when the limiting voltage, characteristic of the electrolyte, is exceeded. At a certain degree of current density there will be a jump in the voltage and a considerable decrease of the current. If this process is reversed, the intensity of the current can be decreased considerably below the value at which the jump in the voltage took place, without occurrence of the inversed transition. If the current intensity is

anode at other locations (places). The arcs will thus disappear in some places and re-appear in others. There is thus a constant change of phases III and IV characterized by appearance and disappearance of numerous arcs.

b. The Course of the Heating Process in an Electrolyte

On the basis of our best results and of the schematic illustrations of the processes, one may form the following concept of the process of heating of the cathode in an electrolyte:

The processes occurring at the cathode depend on two conditions: To obtain luminescence or spark discharge the electrolyte must in the first phase be separated from the electrolyte by an insulating, separating layer, i.e. by deposited gas bubbles. Considering that luminescence or spark discharge occurs at the moment current is applied, the separation of the electrolyte from the electrode is obviously taking place instantaneously during the first phase.

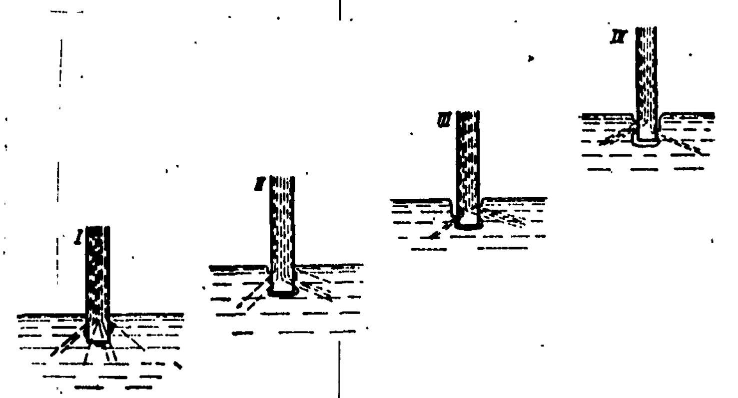
If the layer of the liquid immediately adhering to the electrode is now heated to the boiling point, there will also be formed a vapor envelope surrounding the electrode, as we shall show later on.

According to modern gas theory, vapors form exclusively at the tangential plane between a fluid and a vaporous substance. The formation of vapor bubbles in a boiling liquid is a familiar observation. These bubbles are most readily formed in the presence of air, contained in the liquid, mostly in a dissolved state, deposited often in the form of very fine small bubbles clinging close to the walls of the container. The air bubbles thus form the centers at which the boiling process begins. A liquid free of air bubbles and thus free of boiling centers can, of course, be easily overheated. Placing a solid body, e.g. sand, into such an overheated liquid will cause turbulent boiling since air is introduced into the liquid together with the sand. The formation of vapors in a liquid is thus always dependent on the

still further decreased, the normal process of electrolysis is spontaneously resumed.

Fig. 2: Phases of Transition from Normal Electrolysis to Spark Discharge

The transition from normal electrolysis to spark discharge is shown schematically in figure 2.



Phase I: The current is fairly evenly distributed about the immersed part of the anode which is practically still fully moistened. There will be a moderate formation of gas.

Phase II: The formation of gas is stepped up due to increased current intensity; gas bubbles are displaced less intensively and obtain a large volume (size). The electrolyte is separated from the anode by numerous small or individual large gas bubbles and maintains contact only at relatively few spots. All of the current flows through these few still remaining bridges and the necessarily introduced current density leads to a quicker destruction of the latter by evaporation or through electrolytic gas separation.

Phase III: It comes to the appearance of small electric "arcs" which undergo interruptions.

Phase IV: With partial removal of the gas layer the electrolyte, which had been separated from the electrode, may once more establish contact with the

presence of gas bubbles or a gaseous atmosphere closely surrounding the immersed solid body.

Application of a more or less high voltage leads under these circumstances to the separation of numerous hydrogen bubbles, and the H-bubbles depositing themselves in the vicinity of the electrode represent centers of vapor formation. They cause at the same time here and there (in various places) a partial separation of electrolyte and electrode; as shown in fig 2, a strong current begins to flow through the resulting bridges (the places in which the electrolyte touches the electrode).

These two factors now cause the layer of liquid at the electrode to boil in so short a time that the portion of the electrolyte surrounding this layer does not have sufficient time to cool the layer.

If we designate as:

δ - the thickness of the layer of liquid surrounding the cathode and as

S - the surface of the immersed portion of the cathode

we may state that a quantity of heat

$$Q_1 = S\delta(t' - t) \qquad (1)$$

is required to heat a layer of the thickness δ from a temperature t to a temperature t' if the electrolyte is practically not different from water with regard to its density and specific heat.

The quantity of heat generated during this period of time is according to the Joule Law

$$Q_2 = 0.239\, I^2\, r\, t = 0.239\, \frac{V^2}{R^2}\, r\, t \qquad (2)$$

where R = resistance of the entire chain

r = resistance of the layer having the thickness δ and touching the specimen in question

I = the intensity of the current (amps)

V = Voltage, and

t = Duration of heating. Resistance of the layer having the thickness is:

$$r = \frac{k\delta}{S} \qquad (3)$$

k being the specific resistance of the electrolyte.

Since Q_1 is equal to Q_2 we arrive through equalization of equations 1 and 2 at:

$$S\,\delta\,(t' - t) = 0.239\,\frac{V^2}{R^2}\,.\,\frac{k\delta}{S}\,.\,t \qquad (4)$$

and for the magnitude which interest us here at:

$$\tau = \frac{S^2R^2\,(t'-t)}{0.239\,V^2k} \qquad (5)$$

E.g., if the surface area of a cathode (specimen) of 10 mm diameter amounts at an immersion depth of 2 mm to 14.2 cm^2, the total resistance of the electrolyte and the conductors amounts to 1 Ω, the specific resistance of a 10% Na_2CO_3 solution to 14 Ω/cm, and the voltage to 220 V, we arrive at:

$$\tau = \frac{S^2R^2(t'-t)}{0.239\,V^2k} = \frac{1.4^2(t'-t)}{0.239\cdot 220^2\cdot 14} = \frac{1.96}{162000}(t'-t).$$

This example shows with sufficient clarity that the duration of the first phase of the process amounts with

$$t' = 100^0C \text{ and } t = 20^0C$$

to τ= 0.0016 s, thus in any event only to a few thousandths of a second. The developing H-bubbles will thus cause after a short period of time an intensive vapor formation at the layer of electrolyte adhering to the cathode. Pressure of the separated gas and vapor displaces the liquid at the electrode; this is the beginning of the heating of the cathode thus initiating the second phase of the process.

During that phase the layer of gas enveloping the electrode is especially stable and further heating of the cathode takes place uniformly and in a stable manner. In this second phase we find thus the conditions necessary to

bring about the spheroid state of the liquid, especially the requirement that the cathode surface is heated to a certain temperature. With insufficient H-generation, the heating of the layer of liquid adhering to the cathode is slowed down; the vapors which form themselves are condensed by the great quantity of the electrolyte surrounding the layer, thus impeding initiation of the second phase of the process. The here presented conception of heating metals in an electrolyte furnishes sufficient data for a choice of appropriate sources of current as well as for suitable execution of the process and appropriate composition and concentration of the electrolyte.

3. Factors Influencing the Process of Heating in an Electrolyte

a. Effect of the Source of Current on the Electrical Heating Process

Heating of cathode can also be effected with AC. In that case the luminiscence at the electrode will occur intermittently and is accompanied by a certain noise (crackling of the electric arc) and by splashing of the electrolyte. With a higher voltage, at approximately 380^{o}V, the two phenomena become more pronounced. A further characteristic peculiarity of the heating with AC is the fact that the current density at the electrode is smaller than in the case of DC. With AC heating it will therefore only be possible to heat specimens having a small surface, i.e. a diameter of 3-5 mm.

Tests conducted with more intensive heating of the electrode with AC of normal frequency showed that pre-heating of the electrodes in a furnace to temperatures of 350-400^{o}C permit electrical heating of electrodes having a larger cross section (approximately up to 10 mm diam). Heating can be further improved by applying a layer of mineral oil to the surface of the electrolyte.

For stabilization of the process with AC we used the same methods as used in electrical welding with AC, i.e. a) Increase of the inductivity of the chain, b) Shortening of ignition time by increasing frequency of AC.

The first helps to stabilize the electric arc, inasmuch as a spontaneous-

ly originating current impulse in the coil, which is in series connection with the electric arc, will create the emf of self induction, the motion of which, according to the Lenz law, is in the direction opposite to that of the current, decreasing the intensity of current in the coil. Breaking of the arc and decrease of the current intensity in the coil, on the other hand, will create an emf of self induction in the same direction as that of the fundamental current. This emf increases the current intensity and facilitates ignition of the arc. Our own tests, however, showed that this does not stabilize the process. It is to be assumed that there is no activity during one half of the cycle, so that the intermittent character of the luminescence remains unchanged.

Stabilization of the process can also be obtained by applying a current of high frequency in addition to the current of normal frequency to decrease the duration of ignition. Stabilization is here obtained with the help of an oscillator. The necessary output is taken from a standard welding transformer. The oscillator permits conversion of current of normal frequency and low voltage into current of high frequency and high voltage which facilitates ignition of the arc and stabilizes it.

Tests with this procedure, however, did not yield positive results and thus did not lead to the desired stabilization. Utilization of various sources of current proved that the best heating effect was obtained with DC.

b. Effect of Composition and Concentration of the Electrolyte on the Heating Process

The effect of composition and concentration of the electrolyte on heating of the cathode was investigated in various saline and acid solutions. Changes of current intensity were tested relative to concentration and composition of the electrolyte at constant voltage and with a certain given position (location) of the cathode.

The first group comprises the solutions of the salts of alkali metals (which are at the top of the electrostatic series), as well as acid and alkaline solutions (lyes). The cathode is easily heated in solutions of this first group. The heating process develops with great intensity. Group #2 of the electrolytes comprises solutions of salts of metals placed in the electrostatic series above hydrogen, i.e. the salts of calcium and magnesium. In these electrolytes there will be a deposition of insoluble hydroxide at the cathode. Heating of the cathode requires higher voltages and higher current densities.

Group #3 of the electrolyte comprises solutions of salts of metals placed in the electrostatic series below hydrogen. In these solutions a heating of the cathode occurs only at very high current densities and under special circumstances.

Heating in a Sodium Carbonate Solution

In an aqueous solution of sodium carbonate included in the 1st group of electrolytes, an intermittent luminescence occurs at the cathode at a concentration of 1% and at a voltage of 220V. This luminescence is not accompanied by a heating of the cathode. The Group #3 of the electrolytes must include the solutions of the salts of those metals below hydrogen in the electrostatic series. In these solutions, the cathode is heated only at very high current densities and under special conditions.

The following examples provide an idea of the evolution of the process in the various groups of electrolytes.

Heating in a Solution of Sodium Carbonate

With a current of 120V in a solution consisting of 1% solium carbonate, which belongs to Group #1 of the electrolytes, there is an intermediate luminescence at the cathode but this electroie does not become heated. The heating effects occur only when the solution contains about 4% Na_2CO_3. Thus,

only the first phase of the process will take place in dilute solutions.

Figures 3 and 4 show that the intensity and density of the current increase as the concentration of the electrolyte becomes higher. The increase in concentration also causes the rate of heating of the electrode to increase. In addition to the other figures, figure #5 shows how the current density also changes with the depth of immersion and the cross section of the cathode. It clearly indicates that as the test piece is immersed the current intensity increases at first and then drops. When the work piece is heated in a solution of sodium carbonate, a higher current density occurs temporarily as the piece is immersed. The occurring luminescence is intermittant and is accompanied by splashing of the electrolyte.

Of course, the cathode is not appreciably heated during this phase of the process. Sometime later, the

Figure 3. Dependence between the concentration of the electrolyte and the current intensity for various depths of immersion of the cathode.

Konzentration - concentration

Stromstaerke - current intensity

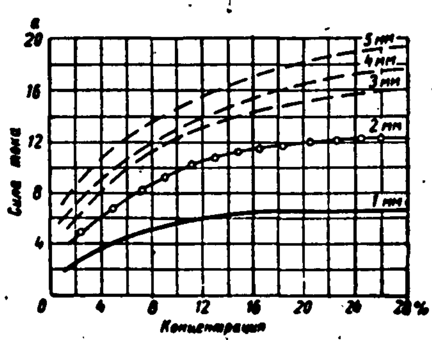
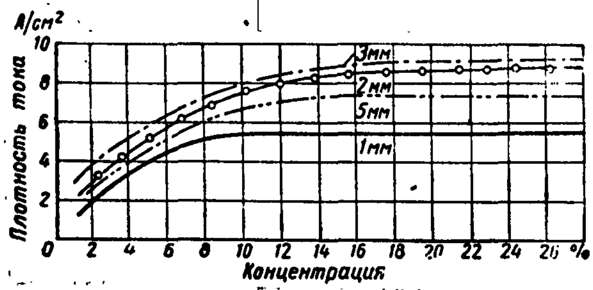


Figure 4. Dependence between the concentration of the electrolyte and the current density for various depths of immersion of the cathode.

Konzentration - concentration

Stromdichte - current density



appearance of the electric arc changes suddenly, the luminescence becomes uniform and glaring and is accompanied by a characteristic noise, the current intensity decreases sharply and the cathode is heated rapidly to the melting point.

Magnesium sulphate belongs to Group #2 of the electrolytes. The described heating effect of the cathode could not take place in a solution of magnesium sulfate at 220 volts. The following process takes place in this electrolyte:

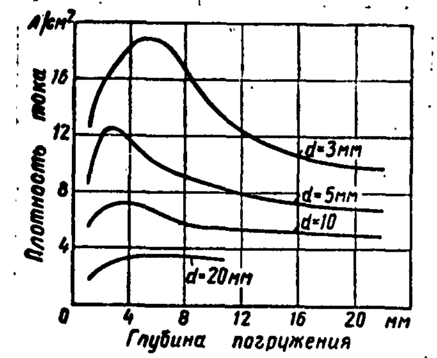
luminescence

Figure 5. Effect of the depth of cathode immersion and its diameter on the current density.

Electrolyte: Solution with 10% Na_2CO_3

Eintauchtiefe - depth of immersion

Stromdichte - current density



does not appear at the cathode when the current is switched on, the solution begins to boil strongly and after a certain period of time a glow is seen at several points of the immersed portion of the cathode, therefore, the current intensity is very low when the voltage is applied and it increases at the cathode as the discharge of sparks takes place. As previously mentioned, this type of process is accompanied by the precipitation of insoluable hydroxides at the cathode. Due to the irregularity of the precipitation of the hydroxides, the current, when increased, is disrupted at individual points and sparks are discharged. When the current is strongly increased the spark discharges appear on a constantly larger surface of the immersed portion of the cathode.

The same phenomena which appear at the cathode in solutions of magnesium sulfate will also occur in solutions of calcium nitrate, which belong to Group #2 of the electrolytes. The hydroxide layer which is deposited in solutions containing 7-8% $Ca(NaO_2)_3$ is destroyed when 220-250 volts are applied. This process is associated with the occurring, uniform luminescence which is accompanied by heating of the cathode.

Heating in a Solution of Copper Chloride

Copper chloride belongs to Group #3 of the electrolytes. With higher currents, sparks jump from the cathode to the electrolyte. The process could not be stabilized in $CuCl_2$ solutions having different concentrations. The

luminescence at the cathode and deflection of the ammeter were of intermittant character. The ~~cathode~~ cathode was not heated under these conditions. In this connection one must keep in mind the fact that the electrical conductivity of the solutions of copper chloride were considerably higher than those of sodium carbonate. Furthermore, one must note that the given characteristics of the individual groups of electrolytes pertain to very specific test conditions (current with 220 volts, test pieces with diameters of 10 mm) which are of significance to the size of the current density at the cathode.

	Occurrence of Spark Discharges			Occurrence of Heating Effect at the Cathode		
Electrolyte	Concentration of the Electrolyte %	Intensity of Current A	Electrical	Concentration corresponding to occurring heat effect	Intensity of Current A	Electrical Conductivity at 18° x 10^{-4}
HCl	0.1	3--4	110	0.5	4--5	520
$MgCl_2$	1.5	3--4	120	22	6--7	1300
Na_2CO_3	1	3--4	130	4	6--8	400
$Ca(NO_3)_2$	1	2	90--100	8	6	550
$Pb(NO_3)_2$	3	5--6	100	--	--	--
$MnSO_4$	3	2	100	--	--	--
$CuSO_4$	2	3	80	--	--	--
$BaCl_2$	1	--	90	3	--	150
Na_2SO_4	1	--	80	10	--	687

Conditions which increase the current density at the cathode intensify the process; when they are applied it is possible to retain the heating effect which occurs in the electrolytes of the 2nd and 3rd group. In regards to the heating effect one might be tempted to explain the variable behaviors of the individual electrolytes by the different electric conductivity of the solutions; however, evaluation of the data received shows that the electrolyte can only influence the time of the spark discharges when weak solutions are used, hence, when the resistance of the electrolyte is the same as that of the gas envelope. These points are confirmed by the test values presented in

Table #1. For the different concentrations of electrolyte, the results show that the time which passes until the spark jumps at the cathode is proportional to the electrical conductivity.

Figure 6. Effect of the electrolyte's concentration on the specific conductivity

Konzentration - concentration

spez. Leitfaehigkeit - specific conductivity

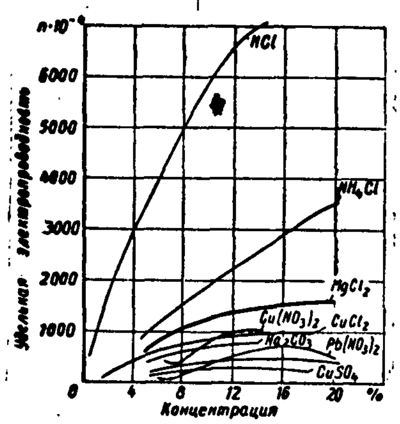


Figure 6 shows that various values of electrical conductivity usually correspond to the various concentrations of electrolyte at which the cathode is heated. Hence, one may infer that the cathode heating is not stipulated by the electrical conductivity of the electrolyte. The behavior of the individual electrolytes, being variable in this respect, is explained by the first phase of the process. As may be concluded from earlier papers, the stability of the vapor envelope which is formed during the first moment of the process depends on the rate at which vapor is produced. When the vapor is produced rapidly the heat released from the adjacent liquid is neglible and the forming vapor envelope will be stable. If the vapors are formed slowly they have time to cool off; the vapor pressure decreases and an unstable envelope is produced. In this case, the cathode is not heated.

The factors influencing the duration of the first phase may be determined through equation #5: $\tau = \frac{S^2R^2}{0.239V^2K} \cdot (t'-t)$

The formula reveals that the time is directly proportional to the square of surface of the immersed piece and inversely proportional to the voltage squared. Hence, one may conclude that the value of τ (duration of heating) may be lowered and that the cathode may be heated in any electrolyte desired by reducing the surface of the immersed portion of the cathode and by increasing the voltage. These facts had been confirmed in experiments.

As previously mentioned, the duration of the formation of vapor is determined for certain voltages and cathode surfaces by the volume of small hydrogen bubbles which are liberated. The volume is determined by the position of the cation in the electrical series.

By considering the solutions which produced the cathode heating effect (Na_2CO_3, Na_2SO_4, $Ca(NO_3)_2$, NaOH, KOH, $MgCl_2$, $BaCl_2$), one may determine that the metals of these salts and lye solutions are at the top of the electrostatic series. An abundant volume of hydrogen is known to develop in these electrolytes at relatively low current densities. On the other hand, the metal is liberated more easily then hydrogen in the electrolysis of salts whose cations are at the bottom of the series. With a gradual increase in current density only metal is at first liberated in such a solution. The simultaneous liberation of metal and vaporous hydrogen at the cathode does not occur until a certain current density is attained. The ratio of this limiting current density to the density of the current at the cathode will be equal to the electrolytic efficiency.

The electrolytic efficiency, as known, is expressed as the ratio of the practically obtained volume of a material to the volume obtained theoretically according to the Faraday Law, i.e.

$$\eta = \cancel{100}\ \frac{P}{q \cdot I \cdot \tau} \cdot 100$$

$$\eta = \cancel{100}\ \frac{I_1}{I_2} \cdot 100$$

in which I_1 = the density of the limiting current and

I_2 = the density of the current at the cathode.

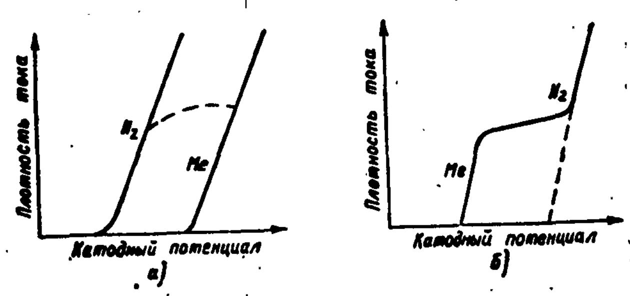
When I_2 is only slightly greater than I_1, most of the current is used to dissociate the metal. But, if I_2 is much greater than I_1, most of the current is used to form hydrogen. Consequently, we also learn the reason why the metal in the solutions of copper salt and the other metals at the end of the series are heated when the current is increased.

Figure #7. Schematic drawing of the position of the polarization curves of the deposition of metal and hydrogen at the cathode.

Stromdichte - current density

Kathodenpotential - cathode potential

The increase of voltage causes the necessary current density; numerous, small bubbles of hydrogen are dissociated and accelerate the formation of vapors, and the duration of the first phase is shortened.



The dissociation of hydrogen and of the metal is schematically presented by the two parts of Figure 7. Figure 7a reveals the first case of electrolysis of a solution containing the hydrogen ions and the ions of an electronegative metal. Only hydrogen is deposited at the cathode.

Figure 7b presents the second case in which metal is dissociated at a potential which, compared to the hydrogen, is positive. This case occurs in the dissociation of electronegative metals, e.g. silver, copper, mercury and lead.

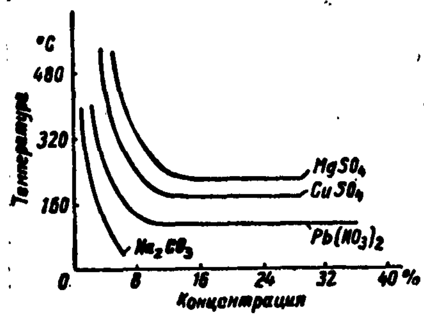
Therefore, the layer of gas at the cathode will only achieve a stable condition under a certain voltage in the electrolyte; the duration of the first phase is short during the stable condition. However, the shortest period for the first phase is characteristic of the solutions in which a large volume of hydrogen is dissociated at a given voltage and current intensity. Solutions containing hydrogen ions and ions of negatively charged metals meet these demands.

The duration of the first phase is essentially a function of the current density i when the voltage is applied and of the number (n) of small, dissociated hydrogen bubbles.

$$\tau = f(i,n)$$

At higher current densities metals, which easily decompose water, may be dissociated from solutions containing the ions of electronegative metals (alkali metals to manganese). This decomposition of water is soon ended in solutions of the salts of manganese, magnesium and aluminum; the cathode is covered by a thin hydroxide film and the current intensity decreases. The film is broken in places when the voltage is increased. Discharges of sparks occur at the openings and the second phase of the process does not take place. When the alkali metals are utilized, the formation of hydroxides does not produce this phenomenon since the hydroxides are easily water-soluble.

Figure 8. Dependence between the required min. temperature of cathode pre-heating and the concentration of the electrolyte for the occurrance of the electrolytic heating effects.



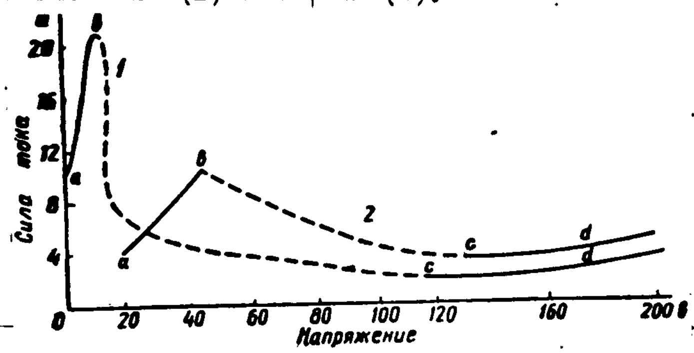
The explosive-like phenomena observed in certain stages of the process are correctly interpreted by the given theory of the electrolytic interrupter. It is substantiated by the fact that the heating effect may be produced with 220 V in all electrolytes ny preheating the cathode. Hence, the appearance of the cathode heating effect is a condition of the formation of the spheroid state (the term "spheroid state" is used here in a transferred sense. It is not applied to a liquid droplet but to a large volume which, like a drop, is also separated from the surface of the electrolyte by the forming gas). This spheroid state can develop in all electrolytes as the cathode is preheated and it is then maintained by the current which is passing through the electrolyte. It is very apparent that a certain preheating of the cathode permits the effect of its electrical heating to be produced at higher voltages. The lowest voltage at which the cathode can be heated electrically is determined by its preheating temperature. Furthermore, the minimum cathode preheating temperature required for the appearance of the cathode heating effect is also found to be dependent on the composition and concentration of the electrolyte. This dependency is presented in Figure 8. It shows that the minimum temperature for electrolytes, into which the cold electrode is placed, is considerably higher and that it decreases as the concentration becomes stronger.

c. Effect of the Voltage of the Source of Current on the Heating Process.

As the voltage is gradually increased, the following phases of the process

may be observed: At low voltages electrolysis takes place first although luminescence does not appear. At increased voltages the characteristic crackling occurs at the cathode; the liquid surrounding the cathode boils so to speak and is separated from the electrode. Strong current variations are caused in the chain corresponding to the spheroid state, the first phase of the process. In this phase, one observes that luminous points, the discharge of sparks, appears between the electrode and the liquid. When the voltage is increased still more, the discharge of sparks is intensified and a luminous envelope is formed in conjunction with a low, uniform sound. The current intensity decreases and the electrolyte boils less strongly. The described change of the current intensity is presented in Figure 9 for solutions of hydrochloric acid and sodium carbonate. At a low voltage there is a strong current intensity for the time being. In solutions of high conductivity, such as hydrochloric acid, the current intensity increases until sparks are discharged. As the voltage is increased after the current density attains a certain value, the discharges occur and then the luminescence appears. This is associated with an abrupt increase in voltage and the corresponding decrease of the current intensity. The luminescence in range bc of the curves (Fig. 9) is irregular and sudden. The first phase of the procedures take place during this period which causes jumps in the ammeter reading (this period is represented by the broken line in Fig. 9).

Figure 9. Dependency of the current intensity from the voltage when using solutions of hydrochloric acid (1) and soda (2).



Through an additional increase in the voltage steady luminescence will appear in hydrochloric acid at 120-130 V and at a slightly higher voltage in soda solutions. However, the cathode is heated only through an increase of both voltage and current density. The d portion of the curves designates the voltage at which the cathode is heated. According to Fig. 9 the cathode in a solution of hydrochloric acid is heated at 220 V at a current intensity of 4 amp, whereas the current density in former tests under like conditions was 8 amp.

The voltage was increased gradually in the last tests but was applied suddenly in the first ones. When the voltage is increased gradually only half as high a current intensity is obtained than for application of the full voltage (220 V) but the heating process does take place with equal intensity and at the same rate. This confirms the fact that approximately the same amount of heat is developed in both cases. When roughly calculating the developed amount of heat to be proportional to I^2R, The following equation must be fulfilled for the case considered: $I_1^2R_1 = I_2 2R_2$ in which I_1 is the current density when the voltage, 220 V, is applied directly and I_2 is the current density attained by gradual increase of the voltage. R_1 and R_2 are the corresponding resistances. Since $I_1 = 2I_2$ according to obtained data, then

$$I_2{}^2R_2 = 2^2(I_2)^2R_1 = 4I_2{}^2R_1$$

and

$$R_2 = 4\ R_1$$

is obtained.

The resistance of the gas envelope which is formed around the electrode when a current of 220 V is applied directly is four times smaller than that obtained under a gradually increased voltage. From this fact, one may conclude that the resistance of the gas envelope may vary under certain conditions although the electrolyte, the voltage and the depth to which the electrode is immersed are alike. The explanation lies therein that the test piece,

subjected to the gradual increase of voltage, remains in the electrolyte for a relatively long period of time and is influenced by currents of various voltages.

The result is an increase of the gas pressure in the gas envelope; consequently, the electrolyte is forced away from the cathode, the thickness of the layer increases and its resistance increases. Therefore, a lower current intensity prevails in this instance than when the current is applied directly with 220 volts.

If the voltage is lowered, one may observe a characteristic hysteresis after the cathode is heated. The voltage may be reduced strongly, e.g. in solutions of hydrochloric acid to 40 V, and the luminescence at the cathode does not disappear but retains all the properties observed at high voltages. The cathode continues to become heated but at a far lower intensity. By decreasing the voltage further, or by holding it at 40 V for some time, the luminescence disappears, sparks are discharged and the electrolyte begins to boil in conjunction with these phenomena of current fluctuations.

The spark discharges, the intermittant luminescence, disappears when the voltage is reduced further; the current intensity rises suddenly, electrolysis takes place. Figure 10 presents the relation between the voltage and the current intensity while maintaining the given conditions. It shows that this dependency in the voltage range in which heating of the cathode is observed follows the Ohm law to a certain extent, i.e. the decrease in current intensity is proportional to the decrease of voltage. Figure 10 also reveals that the voltage at which the heating effect ceases is different for each electrolyte. Therefore, the cathode may be heated under very variable electrical outputs.

Figure 10. Dependency of the current intensity on the voltage in various electrolytes. Stromstaerke - current intensity

Spanning - voltage

Fig. 10

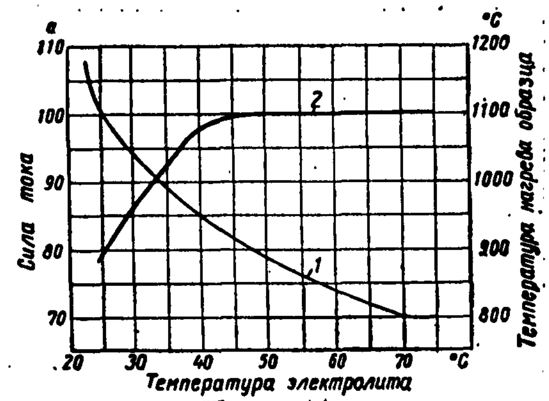


Fig. 11

The time required for heating of the cathode must quite obviously be proportionate to the rate of power input. With a low output, the heating time increases thus in the same proportion as the input at a high voltage must be greater than the input required for heating at a low voltage. Therefore, by maintaining a stable layer of gas at reduced voltage, slow heating is made possible. Recognition of this fact constitutes the basis for control of the rate of heating in actual application.

d. Effect of the Temperature of the Electrolyte

Table #2 shows the changes of current intensity as a function of the immersion depth of the cathode (diameter of 16 mm and length of 40 mm) with various electrolyte temperatures (15 and 60°C). (Compare with Fig #11.)

Table 2

Immersion depth of the cathode in mm	Current intensity A, temperature of electrolyte - 60°C in amp.	Current intensity A temperature of electrolyte - 15°C in amp.
		3
1	10	4 - 6
2	12	6 -10
3	14	8 -10
4	18	10 -12
5	22	

Figure 11 shows that the current intensity decreases and that the resistance of the gas envelope decreases with the increase of the temperature of the electrolyte. In this case one must consider that the resistance of the electrolyte decreases with the increasing temperature.

Figure #11. Current intensity (1) and heating temperature of the test piece (2) as functions of the temperature of the electrolyte.

Stromstaerke - current intensity

Temperatur des Elektrolyten - temperature of electrolyte

Erwarmungstemperature der Probe - heating temperature of the test piece.

As the temperature of the electrolyte increases, the electrolytic formation of gas at the cathode and the gas pressure in the forming envelope also increase. The volume of the gas envelope becomes greater and the electrical resistance becomes higher.

The increased heating observed when the temperature of the electrolyte rises with less applied energy is a condition of the nature of the heating effect; it will be discussed in detail later.

The gas envelope becomes unstable when the temperature of the electrolyte is raised considerably, to more than 80°C; it is destroyed by the developing vapors. In these cases, one observes irregular jumps in the ammeter indications and the electrolyte spatters; the luminescence at the cathode is of the same character as that encountered in alternating current.

The effect of the temperature of the electrolyte on electrical heating of a metal in an electrolyte is summarized as follows: the temperature of the electrolyte must be constant at 50° to° 70 .

e. Effect of the Surface Finishing of the Work Piece on Heating.

As previously mentioned, the spheroid state of the electrolyte depends on the surface finishing of the work piece. The motion of the spheroid on rough surfaces is rapid and irregular, a constant jumping on the explosive-like destruction of the spheroid.

All circumstances which influence the course of the spheroid state as a result of the surface finishing are reflected in the electrolyte in the heat-

ing process. The concentration of the electrolyte is far less for a test piece with ground surfaces than for one with roughly treated surfaces.

The heating differences caused by the various surface finishings of the test pieces are balanced for the concentrated solutions which are in practical application in electrical heating. The surface finishing only manifests itself to some degree in the first phase. This period is shortened in the case of a smooth surface. The following may be established as a valid fact: an increase of the concentration of the solutions contributes toward greater stability of the gas layer at the envelope.

f. Heating as a Function of the Current Intensity at the Electrodes.

An indispensible prerequisite to heating of objects in electrolytes is that the cathodic current density be greater than the anodic density.

For instance, a test was conducted with a steel test piece, with a diameter of 10 mm, in a small tank which measured 20 x 15 x 8 cm and acted as the anode. The test piece was immersed 2 mm and cathodically heated. The anodic current density, in this case, was about 800 times lower than the cathodic current density but the difference in current densities employed at the electrodes to heat the cathode may be considerably lower. The following experiment was conducted to determine the optimum value or practically necessary difference of current density at the electrodes:

Two cylindrical test pieces, each 10 mm in diameter and used as cathode and anode were placed 10 mm apart in a test electrolyte. The cathode was immersed 5 mm into the electrolyte and the anode was lowered gradually. At first, while the surface of the immersed portion of the cathode exceeded that of the anode, some luminescence was observed at the anode while a cloud of dissociated water formed around the cathode.

Ignition occurred at the cathode when the anode was immersed to a certain depth. As the arc of light occurred, the luminiscence at the anode again.

A constant luminescence appeared at the cathode when the anode was immersed further.

Table 3 shows what happens at the anode when it is immersed to various depths.

Table 3

Depth of anode immersion in mm	Current Intensity in Amp.	Characteristics of the occurrence
1	1	luminescence at the anode
2	1.8	" " " "
3	2	" " " "
4	2.3	" " " "
5	3	" " " "
6	3.5	" " " "
7	3.5	" " " "
8	3.8	" " " "
9	13	" " " "
		Occasional ignition observed at cathode
		Constant luminescence at the cathode

Through Table 3 it is possible to calculate the differences of current densities required at the electrodes to heat the cathode.

When l_1 is the depth of cathode immersion

l_2 is the anode depth of immersion

r is the diameter of the electrode and

i is the current intensity

and with equal diameters for both electrodes, the current density at the cathode is

$$iK = \frac{i}{\pi r^2 + 2\pi r l_1}$$

and the current density at the anode is

$$i_A = \frac{i}{\pi r^2 + 2\pi r l_2}$$

The ratio of current density is obtained by dividing the two equations:

$$\frac{iK}{i_A} = \frac{r + 2l_2}{r + 2l_1} = \frac{5 + 18}{5 + 10} = 1.5$$

Therefore, in this case the cathodic density was 1.5 times the anodic density.

In these tests the current was applied as the anode was immersed.

However, when the current was applied before changing the depth of anode immersion a constant luminescence appeared at the cathode while the anode was only slightly immersed. Consequently, the cathode was heated while the values for the current densities at both electrodes were nearly the same.

4. Control of the Rate of Heating in an Electrolyte

Control of the rate of heating (speed) can be effected:

1. By changing composition and concentration of the electrolytes.
2. By changing voltage or current density.

It may also be controlled by the method used, e.g. by varying the speed of rotation or deflection of the specimen to be heated.

The most simple method of controlling the rate of heating is the method of changing the voltage.

Our tests proved that the rate of heating can be decreased and the cooling time slowed down by decreasing the applied voltage.

The effect of the rate of heating was investigated with specimens of c-steel 40 of 10 mm diameter. Test samples were heated to hardening temperature using various heating conditons, and subsequently hardened by quenching them in water. (see Table 4)

Table 4

Concentration of Na_2CO_3 Solution %	Immersion Depth of Cathode (mm)	Duration of Heating sec.	Amperage A	Voltage V	Depth of Hardened Layer (mm)* First appearance of Ferrite	Total Depth
5	2	8	6	220	2.3	3.3
10	2	4	8	220	2.3	3.0
10	2	8	6	180	2.6	3.6
5	3	5	8	220	2.9	3.6
10	3	4	10	220	3.0	3.6
5	5	5	12	220	6.4	7.0
10	5	4	14	220	5.8	6.2
10	5	7	12	180	5.2	6.0

* Investigation of the structure showed martensite in the external zone.

Summary evaluation shows that electrical heating in an electrolyte offers considerable advantages over customary processes of local heating and surface heating be external sources of heat. The process permits a heating of the electrode to substantial depths without overheating the surface. The new method also permits the execution of thermal processes requiring maintenance of a certain temperature and slow heating or cooling of the object in question.

5. The Essence of the Heating Effect in Electrolytic Heating

The described cathodic heating effect is based on certain resistance to the passage of current caused by the gas envelope formed at the cathode. The passage of current through such a resistor is accompanied by the development of Joule heat which causes a heating of the cathode. The author's tests show that the processes taking place in an electrolyte at higher voltages do not follow the well known laws of electricity; the above cited explanation of the heat effect, is furthermore not fully in agreement with the actual circumstances. The heating effect is probably to a large extent bound up with exothermic reactions occurring in the gas medium, and possibly also with atomic or molecular transmutations of the hydrogen.

Previous test comparing data on heatings in Na_2CO_3 and HCl solutions (fig. 9) show that the intensity of cathode heating in a HCl solution at low voltage and low current density, i.e. with a smaller energy, is equal or even higher than that obtained in Na_2CO_3 solutions. The same characteristics were observed when the heating process was made with gradual increase or with a constant voltage. In the first case, the desired temperature is obtained with less current density and less expenditure of energy than in the second case. Finally, one will observe that the intensity of heating and the required energy will decrease if the heating is made in a pre-heated electrolyte.

The decrease of current density is explained by the formation of a thicker layer at the cathode which thus has a larger resistance. In HCl solutions and

in pre-heated electrolytes, the formation of such a layer is connected with an increase of hydrogen generation. With a gradual increase of the voltage, on the other hand, this formation of the layer is a consequence of a longer duration of the period of gas formation.

All of the here described phenomena cannot be explained in the form of a schematic presentation (fig. 2) or by the conception heat is generated excensively as a consequence of the passage of current through a relatively high resistor (gas envelope).

The phenomena thus do not conform to the known laws of electricity and can be explained only as a number of exothermic reactions in the gas medium. Quite convincing are in this respect a number of tests which showed that the anode was the active electrode, o.e. that the surface of the anode was greater than that of the cathode.

In a previous paragraph we mentioned that intermittent spark discharges occur at the anode at lower voltages, i.e. at approximately 200 V, accompanied by crepitation and splattering of the electrolyte. In certain electrolytes, e.g. in solutions of the salts of alkali metals, we observe at voltages of 400 V at the anode a constant well observable gas envelope in the form of a gas bubble, composed mainly of oxygen. At 400 V, the above-mentioned fluctuations of the ammeter needle as well as the splattering and the characteristic crepitation of the electrolyte cease earlier. In all tests conducted, the anode did not heat up and only in a few instances was a heating of the electrolyte observed. Tests conducted at high voltages showed that the presence of a constant gas envelope is not sufficient to heat an electrode, and that a heating of the cathode is dependent upon the formation of a hydrogen envelope.

It has been repeatedly stated that a heating up of the cathode is accomaanied by a characteristic crepitating noise. The light effect to be observed on the surface of an electrode reminds one of the luminescence of electrical

discharges. Flames of various sizes surrounding the cathode seek to detach themselves from the surface of the electrolyte. These flames are probably caused by combustion of hydrogen or by the formation of detonating gas resulting from electrolytic decomposition of the vapors of the electrolyte. The probability that these reactions take place is substantiated by the following test: If the cathode is covered from above with a bell glass, one will observe after some time that the receiver is filled by the electrolyte, and the heating of the cathode ceases, due to the fact that the atmospheric oxygen participates in the reactions taking place in the gas medium, thus decreasing pressure within the bell glass which is then filled with the electrolyte. From these observations we may draw the following conclusion: To increase the electrolytic efficiency produced by the process of heating in an electrolyte it will be necessary to produce the condition of most intensive hydrogen formation at the cathode.

The here described procedures and conditions for intensification of hydrogen formation at the cathode, such as an increase of current density, suitable composition and concentration of the electrolyte, increase of the electrolyte's temperature, do not comprise all possibilities to obtain the desired effect.

In concluding this chapter we want to point out that the above-mentioned data concerning the energy required for electrical heating of work pieces and individual components, enabling us at the same to determine the electrolytic efficiency of the process have been established without sufficient consideration of all factors increasing this current yield. The data must therefore be considered as being too high.

CHAPTER II

METHODS OF HEATING IN ELECTROLYTE

Our works, dealing with the various methods of heating in an electrolyte, were directed towards the solving of a number of problems related to local and surface heating of the details as well as the end heating of the details and blanks for thermal processing, drop forging soldering and others.

In accordance with this the methods we have developed can be broken up into four groups: methods of end heating, methods of local and surface heating, methods of sequence heating and the methods of heating with a fixed shielded cathode.

END HEATING

End heating of details and blanks is one of the most widespread methods of heating employed by industry.

Thermal processing of details, which is employed in connection with end heating, is usually accomplished in hydrochloric and lead baths and in some cases - with the aid of oxy-acetylene flame.

For end heating with hot mechanical processing one usually employs oil or gas furnaces of various constructions. In some cases,

particularly for the heating of rivets, an electrocontact method of heating is employed, achieved through the use of various electro-contact devices.

All these methods have a number of significant weaknesses. A common weakness is a small productivity. Most of these methods cause problems in cases when the area of heating has to be limited; this is of great importance during the thermal processing of many details. Thus, for example, great problems arise when heads of threaded bolts are heated for tempering in lead and other baths. In this method of heating some of the threads become tempered, deformed and filled with lead. All this leads to low quality processing, or the necessity of introducing additional operations for cleaning and correcting of the threads.

Another example where it is important to limit the area of heating is the heating of the end of a valve for tempering. The end of a valve has to be heated for tempering for a length of 4 - 6 mm. The heating of the end of the valve for a greater distance causes brittleness and a valve failure at the bearing chamber.

Additional drawbacks of the ordinary methods of end heating are, in some cases, a low efficiency of the aggregates, the harmfulness of the process (lead baths) and others.

It is of importance to note that the application of the electrocontact method of heating, which possesses many of the weaknesses stated above, is very much limited due to the necessity of obtaining of a good contact at the heated surfaces. A bad contact, as can be expected, results in melting and nonuniform heating of the part.

The end electroheating in an electrolyte has significant advantages over all of the above discusses methods.

One must differentiate between two methods of end electroheating in an electrolyte: the heating of the free end and the heating when the end cross sectional area is shielded.

HEATING OF THE FREE END

The first method of the end heating - "the heating of the free end" - was developed by us in 1937 and installed in production at HTZ (chemical technical plants?) for the tempering of valve ends, the heads of regulating and lock screws of a motor.

In principle the scheme of this method does not differ much from the previously investigated scheme of the production of the heating effect in the electrolyte (see Figure 1). Here the detail 1 (Figure 12). which is the cathode, is immersed into the electrolyte for a specified depth. The

metal bath 2 of the electrolyte is connected to a positive pole.

Our first [redacted] experiments in the course of developing a production method have shown that, in order to attain a constant temperature of heating of the parts, all other conditions being the same, it is necessary to maintain their depth of immersion into the electrolyte at a constant. These experiments have also shown that small deviations in the immersion depth can, in one case, lead to a sharp overheating and melting of the part and in another case - to an insignificant heating. This situation is clearly evident from the data given in Table 5 dealing with the heating of valve ends immersed into the electrolyte for different depths. It is evident that the changes in the heating intensity, depending on the depth of immersion of the detail into the electrolyte, or the area of the heated surface are related to the changes in current density as shown in Table 5.

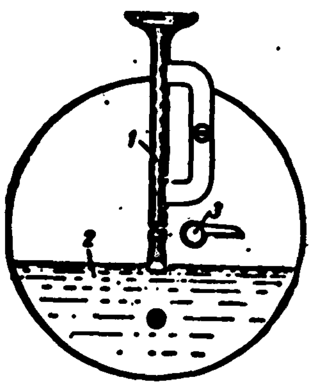


Fig. 12

The scheme of heating of the free end in the electrolyte.

In our opinion the stated peculiarity, relating the effect of the current density on the cathode on the heating intensity, was not considered by other authors who made earlier attempts at utilizing the heating effect of the cathode in industry; therefore this problem remained unsolved.

TABLE 5

Heating conditions				Characteristics of the structure after thermal processing
Max. immersion depth into the electrolyte in mm	RPM of the operating disc	Heating time in sec	Depth of tempered layer in mm	
3	1.7	5	-	Insufficient heating
4	1.7	7	3.0 - 3.3	Corresponds to normal tempering
5	1.7	8.3	4.0 - 4.5	Same as above
2	1.4	3.5	-	Insufficient heating
3	1.4	7	2.4 - 2.7	Corresponds to normal tempering
4	1.4	8.2	3.3 - 3.8	Same as above

(TABLE 5 continued)

5	1.4	8.7	4.5 - 5.0	Overheating
2	1.2	5	-	Insufficient heating
3	1.2	8	2.5 - 3.0	Corresponds to normal tempering
4	1.2	9	4.3 - 4.8	Overheating
2	1.0	7	-	Insufficient heating
3	1.0	9	4.0 - 4.5	Symptoms of overheating
4	1.0	9.5	5.0 - 5.5	Overheating

The principal difference in the method of the free end heating, which we have developed, (as compared with previous methods ?) is the introduction of the device 3 to the heating assembly (see Fig. 12); this device guarantees a constant depth of immersion ~~xxx~~ of the details into the electrolyte.

The disadvantage of the studied method is that its application is limited by the cross-section, shape and length of the heated end of the part. With an increase in cross-section and length of the heated end the variations in the current density in the separate spots to be heated manifest themselves on the heating effect. The same also holds for

an irregular cross-sectional area at the end of the detail. This condition results in the melting of the end area and, in the first place, its sharp edges and protruding parts. Therefore, the practical application of this method was limited by heating for tempering of the parts to samples having cylindrical or spherical ends of a 15 mm diameter, for which it is required that the depth of the tempered layer be 5 - 10 mm.

As an example of such details, as stated above, one can mention the valve and some screws for which this method was actually employed.

A wider application of the method of heating of the ends of the details in an electrolyte has become possible as a result of the development of our method - "heating when the end cross-sectional area is shielded."

HEATING WHEN THE END CROSS-SECTIONAL AREA IS SHIELDED

As mentioned previously, the phenomenon of heating of the cathode in an electrolyte is related to the existence of a definite value of current density. The heating intensity is dependent on the current density.

It follows that at a nonuniform distribution of the current density on the cathode the latter will heat up more at points where the

current density is larger.

In order to decrease the current density on the end cross-sectional areas of details and blanks, but mainly on their sharp edges and protruding parts, various methods of isolation and shielding of the end cross-sections have been tested.

The most effective and practicable method turned out to consist of the requirement that the details and blanks, prior to being immersed into the electrolyte, be placed with their end cross-sections on a fireproof, insulating material. For this purpose a fireproof brick was selected. Such a method of insulation, or shielding of the end cross-sections permits, as will be shown later, at the same time, to realize also the first requirement from the structural point of view, namely, the guaranteeing of a constant depth of immersion into the electrolyte.

From the basic scheme of the second method, shown in Fig. 13, it can be seen that the details are immersed into the electrolyte only after having first been placed with their end cross-sectional areas on top of the shield XXXXXXXX (insulator). The current is conducted to the terminals which fix the details. By using shields of various shapes one can easily smoothen out the current density and consequently, obtain a uniform heating of ends of details which have complicated shapes or non-uniform cross-sections.

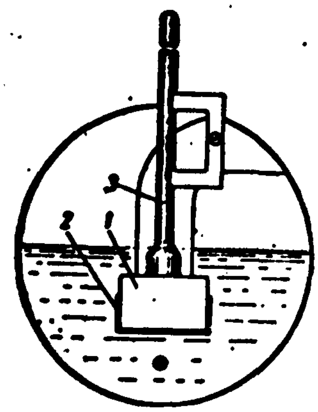


Fig. 13

The scheme of heating in an electrolyte when the end cross-sectional areas are insulated (shielded):

1 - insulator (shield); 2 - electrolyte; 3 - heated detail

As an example Figs. 14 - 16 show different forms of shields used for such details.

The first form of the shield (see Fig. 14) is used for heating the end of a connecting rod of a tractor engine.

The end of the connecting rod of the engine, having the shape of a cup with sharp edges, is heated for tempering for a length of 25 - 30 mm. For such a nonuniform cross-section of the heated end, in

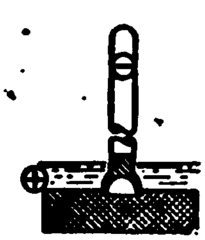


Fig 14 Insulator (shield) for heat-

Fig 15 Insulator (shield) for the

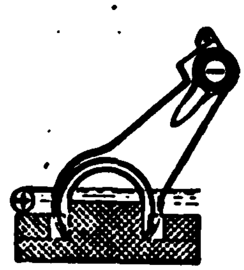


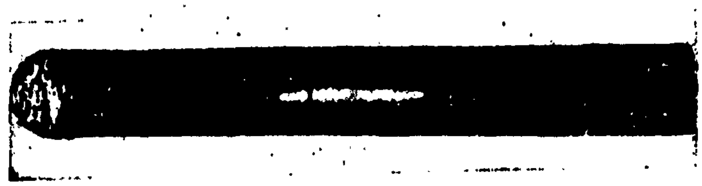
Fig 16 Insulator (shield) for heat-

ing of a conn-	heating of the end	ing a shift fork
ecting rod of an	of a fork with sharp	
engine	edges	

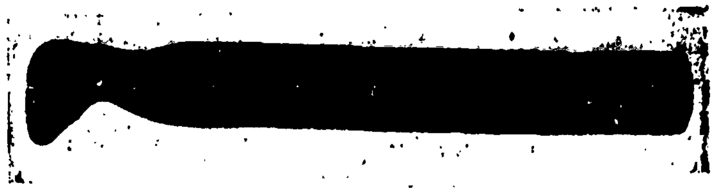
ordrr to attain uniform heating, aside from shielding the end cross-sections, it is necessary to also partly shield the lateral surfaces. Accordingly, heated details are placed into cylindrical nests 5 mm deep and 25 mm in diameter drilled into the shield.

It should be pointed out that the heating in an electrolyte of the end of an engine connecting rod using the first method could not be accomplished without the melting of sharp edges of the cup even for a short length (3 - 5 mm).

Fig. 15 shows a shield used for heating the ends (forks) of a release lever of a tractor.



a)



b)

Fig. 17. Melting of the end cross-sectional areas of cylindrical samples during electrolytic heating:

a- melting at free end heating   b - melting at shielded end heating

In such a case, aside from the end cross-sections, interior surfaces of the forks which have sharp edges are also shielded.

The shield shown in Fig. 16 is used for shift forks.

The ends of forks are subjected to tempering for a distance of 40 - 50 mm. Here, besides the end cross-sectional areas and interior surfaces of the fork, exterior surfaces of the ends, having smaller sections, are also shielded.

It must be pointed out that in many cases of shielding it is not required that good fit coverage of the surface of the detail be prvided by the shield. This can be seen from the shape of the shield employed for heating of one of the two ends of the fork shown in Fig. 16. Here a gap of 2 - 3 mm can exist between the shielded parts of the detail and the shield itself.

The effectiveness of the new method can be easily observed from the character of melting on cylindrical samples during heating. If the samples were subjected to heating in accordance with both discussed methods, i.e. the method of "heating of the free end" and heating

when the end cross-sectional areas are shielded, raising their temperature to the melting point, then in the first case melting starts at the end cross-sectional areas (Fig. 17a), but in the other case melting begins at the midpoint of the area immersed into the electrolyte (Fig. 17, b).

REGIME AND CONDITIONS OF END HEATING

The conditions of heating of the cathode in an electrolyte at a given voltage and a given current density depend on the composition of the electrolyte.

Of all the electrolytes tested by us for purposes of use by industry we recommend solutions of sodium carbonate (Na_2CO_3) or potassium carbonate (K_2CO_3). The advantages of these electrolytes are that the heating occurs with sufficient intensity; with this they do not cause any corrosion on the metallic details of the heating devices and are also acceptable as far as safety of the operation is concerned.

Table 6 gives electrical operating conditions during heating of the samples in accordance with both discussed methods and at same depths of immersion (diameter of the sample is 10 mm). The data of Table 6 shows that the difference takes place only in relation to the value of the current.

TABLE 6

Depth of immersion in mm	Voltage in volts	Heating of the free end		Heating with a shielded end	
		Current in amps	Current density in amps/cm^2	Current in amps	Current density in amps/cm^2
2	250	6—8	4—5,5	2—3	3—5
4	250	12	6	4—6	3—5
6	250	16	6	6—8	3—4,5
8	250	18—20	6,5—6	12—14	4,5—5,5
10	250	22	5,5	16	5
20	250	23—32	4,5—5	28—32	4—5

Data on current density at different immersion depths given in the same table shows that the variations in the values of the current can be attributed to an increase in the "active" surface during heating of the free end of the sample, i.e. the presence of unprotected end cross-sectional areas.

Heating intensity for a given composition and a given temperature of the electrolyte depends on the voltage of the current source and the

current density on thecathode.

TABLE 7

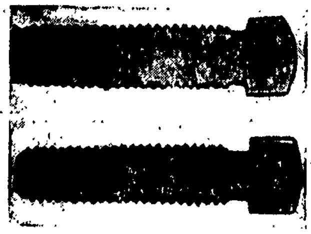
Name of detail	Heating regime			Length of tempered end in mm
	Depth of immersion into electrolyte in mm	Voltage in volts	Time in sec	
Look screw	10	260	10	8
Same	10	295	5	8
Regulating screw	18	260	8	15
Same	18	300	5	15
Lathe driver pin	23	250	7	17
Same	23	290	5	17
Grader	27	310	10	22
Same	27	270	20	22
Same	20	285	12	14
Valve rocking arm	20	235	10	16
Centrifugal disconnection lever	18	240	20	14
Lathe dowel	30	275	8	25
Shift shaft lock	15	275	7	13
Engine connecting rod	30	275	16	25
Body of disconnection bearing	28	280	20	22
Valve	10	300	6	6
Shift fork	45	240	13	42
Reverse shift fork	45	240	13	42
Release lever	30	220	15	25

14

For the electrolyte we have employed(Na_2CO_3) with a 5 - 10% concentration, the voltage must be of the order of 200 - 220 volts and the current density 3 - 4 amps/cm^2. With an increase in the voltage and the current density there occurs an increase in the intensity and speed of heating.

In this manner the [redacted] heating regime (speed and temperature) is determined by the magnitudes of the following parameters: voltage of the current source, current density, heating time, concentration and temperature of the electrolyte.

Table 7 gives a number of examples of heating regimes for tempering of certain details of a tractor and using the method of shielding of the end cross-sectional areas; Figs. 18 - 24 shows the macrostructure of the tempered parts.



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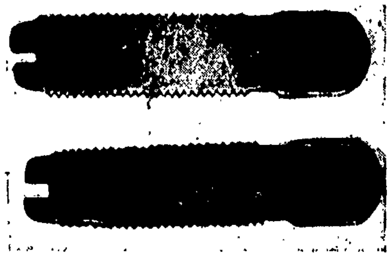

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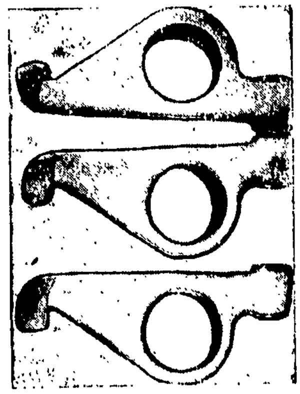

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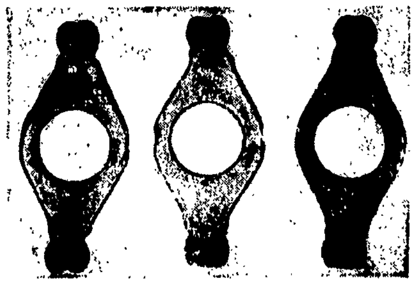

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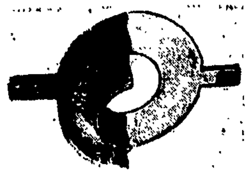

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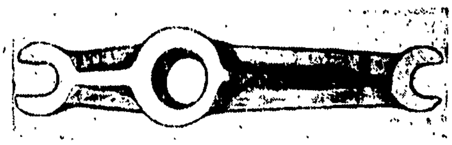


23.

Macrostructure of tempered details after electrolytic heating.

Table 8 gives several heating regimes, using the same method, for blanks to be used for hot stamping of bolts.

Fig. 24 Macrostructure of a tempered detail after electrolytic heating

As far as the possible length and section of the heated end of the details or blanks is concerned, for the first method, as was stated above,

the length and the section are very much limited, however, for the se-

TABLE 8

Blank diameter in mm	Depth of blank immersion in mm	Length of heated end in mm	Heating time in sec	Voltage in volts	Current in amps	Power in kw	Expended energy in kw-hrs
10	10	10	4	290	24	7	0,0077
10	10	10	10	200	14	3	0,0078
10	20	20	5	290	40	12	0,016
10	20	20	15	200	22	4,5	0,018
10	30	30	8	290	34	10	0,022
16	10	10	8	280	27	7,5	0,017
16	20	20	10	290	47	13,5	0,038
16	30	25	14	295	48	14,5	0,054
20	10	10	16	295	20	6	0,026
20	20	15	20	290	32	9	0,050
20	30	20	20	290	50	14,5	0,080
42	20	16	30	245	65	15,9	0,133
42	40	32	40	245	140	34,3	0,381
42	60	50	50	245	200	49	0,681

cond, i.e. heating with shielded end cross-sectional areas, this possibility is determined by the power of the current source, i.e. motor--generator.

Here it should be pointed out that the method of heating with shielded end cross-sectional areas will result in full heating of the detail"

if the end cross-sections are used directly as current terminals.

As an example we can use the heating regime of blanks with a diameter of 54 mm and a length of 50 mm.

Such a blank will be heated to 1300° C in 45 sec provided that the applied voltage be 245 volts and the current 250 amperes.

In carrying out the work we used motor-generators with a power of 30 kw at 300 volts and 90 kw at 250 volts. These powers permitted us to conduct the heating of parts of details with a total surface area of the order of 30 - 40 cm^2 and 90 - 100 cm^2.

The use of more powerful generators permits to significantly increase the sections and length of a possible heating and thereby to make the utilization of this method more widespread.

2 LOCAL AND SURFACE HEATING

In recent years a significant place in technology has been occupied by local and surface heating for purposes of tempering of machine parts.

Surface tempering increases the wearresistance of the details, eliminates in some cases a lengthy and costly process of carburizing and in some cases permits one to use ordinary carbon steels in place of alloy steels, and the like.

At one time the method of surface tempering with the aid of oxy-acetylene flame was sometimes employed for surface hardening of bearings of different shafts.

Later on this method was by and large displaced by the method of heating using high frequency current, as developed by professor Vologdin. Heating with the aid of high frequency current is finding wider and wider applications in our industry.

As was pointed out before, the method of tempering, achieved by heating with high frequency current is distinguished by its advanced technology, is highly productive and permits high quality treatment of the details.

This situation, however, did not exclude the usefulness of further research and the development of new methods of surface heating.

One of unquestionably rational and perspective methods of local and surface heating is the method of heating in an electrolyte we developed.

The three basic methods of surface heating in an electrolyte, as developed by us can be classified in the following way:

First method - heating with an immersion into an electrolyte

Second method - heating in an electrolyte jet

Third method - heating by way of contact with a porous insulator.

HEATING WITH AN IMMERSION INTO AN ELECTROLYTE

The basic scheme of the method of surface heating with an immersion of the detail into an electrolyte is given in Fig. 25.

From this scheme it is evident that this method can be applied to disc shaped details which require the tempering of a cylindrical surface.

On one of such details, namely, the supporting roller of a tractor suspension we conducted experiments on this method. The tractor suspension roller must have a high degree of hardness along its circumference. The usual method of thermal processing of the roller consists of the heating of the entire detail in a universal oven followed by circumferential tempering in a special device which furnishes cooling water, in the form of a shower, only in the radial direction.

From here it can be seen that from a point of view of increasing production and improving quality of the detail, the method of surface tempering becomes of considerable interest.

In our experiments the roller was mounted on a shaft and put into a rotating motion. Under the roller was placed an electrolyte bath in such a manner that part of the roller, approximately 0.15 of the

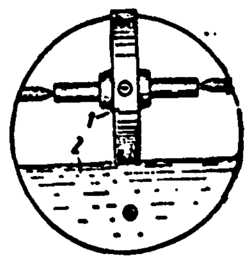


Fig. 25.The scheme of surface heating with the immersion of a part of a detail into an electrolyte: 1 - detail; 2 - electrolyte

circumference (70 cm^2) was immersed in the electrolyte. The detail was connected to the negative pole and the electrolyte - bath to the positive pole. By this method the circumference of the roller was heated in two ways: during several revolutions and during one revolution.

The former of these methods, as is known, consists of the detail rotating so that one or another of its parts sequentially passes through the zone of heating. Gradually, after several revolutions, the heated surfaces of the detail reach the required temperature, after which follow the cooling operations on the entire detail. In the latter method the detail rotates with a very small velocity, calculated in such a manner so that during the passage through the heated zone of one or another part of the surface the latter would be heated up to therequired tempering temperature.

Cooling of the detail for the tempering in this second method of heating must be achieved directly after the heated area exits from

the heated zone.

The heating of the roller in the first case was conducted at 220 volts. Expended power consisted of 65 kw. Rotation of the roller was at 60 RPM. Under these conditions the circumference of the roller heated up to 850°C in 15 minutes. The rather lengthy period of time, spent on heating of one detail, can be attributed to large heat losses due to a large diameter of the detail. The large diameter of the detail manifests itself by the fact that at any given moment a large surface area, subject to heating is situated outside the heated zone and is cooled by surrounding air.

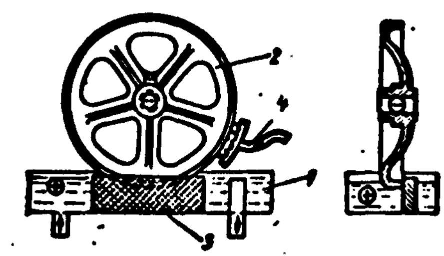


Fig. 26. The application of the shower device when heating in an electrolyte during tempering: 1 - electrolyte; 2 - detail; 3 - insulator (shield); 4 - shower device during tempering.

The heating of the roller in the second method (heating during one revolution) is conducted at 260 volts. Expended power was 75 kw. The required tempering temperature at these conditions was attained with

the roller rotating at 0.2 RPM. In this heating method, the tempering, as is shown in Fig. 26., can be accomplished with the aid of the shower device located directly at the exit of the heated surface from the heated area.

It must be pointed out that in order to eliminate overheating of the cross-sectional area of the circumference, fireproof brick shields, depending on the construction of the detail, are placed into electrolyte bath. In the case of the roller, as shown in Fig. 26, uniform heating of the rim is attained with the installation of only one of such shields.

Our experiments dealing with the heating of rollers permit us to state that the method of surface heating with the immersion of the details into an electrolyte and attained during several revolutions can be very effectively used for details with a diameter of 100 - 150 mm.

For details with larger diameters it becomes more practicable to use the method of heating during one revolution.

HEATING IN AN ELECTROLYTE JET

The method of local surface tempering is very effective

in the processing of various ~~shafts~~.

Our experiments in connection with electroheating in an electrolyte of such details led to the development of a new method - the heating in an electrolyte jet.

The basic scheme of this method is shown in Fig, 27.

If the detail 1 is connected to the negative pole of DC and the metal tube 3, through which the electrolyte is conducted, - to the positive pole, then at a certain separation between the tube and the detail the latter is heated up at the spot of its contact with the electrolyte jet. The heating intensity in this case depends , aside from such factors like the properties of the electrolyte, current density and other closely scrutinized factors, discussed in chapter 1, on height and the cross-sectional area of the jet.

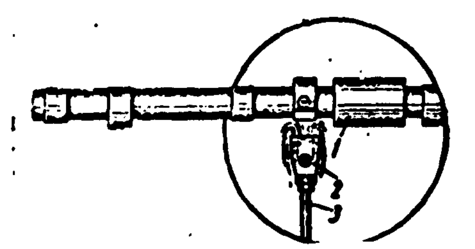


Fig. 27. The scheme of surface and local heating in an electrolyte jet

In the case of the practical application of this method it becomes

profitable to conduct the heating with a short jet, since in that case the resistance to the jet is decreased and consequently, at a given voltage a higher current density can be obtained. However, the shortening of the jet is limited by a certain distance between the tube and the detail. Beyond a certain point, with a further decrease in this distance a short circuit occurs between the tube and the detail. This defficiency can be eliminated with the installation on the end of tube 3 (see Fig. 27) of a special nozzle 2 made of a fireproof, insulating material (china, quartz and the like) and protruding above the tube for a distance of 5 - 10 mm.

Experiments in connection with the application of the method of heating in an electrolyte jet were conducted by us on cam (distributing) shafts of tractor engines.

Cam, or distributing shafts must possess a high degree of hardness at the cams.

The application of a local surface tempering to the cam shaft permits one to avoid a costly and lengthy process of carburizing and and to avoid the required use of better steel for the details. This is substantiated by the fact that in a number of our homeland plants today surface tempering of cam shafts is attained with the heating by high frequency currents.

See Page 61a for Figure 28

Fig. 28. The scheme of the laboratory apparatus for tempering of cam shafts through heating in an electrolyte.

Fig. 28 shows the scheme of the laboratory apparatus for tempering of a cam shaft through electroheating in an electrolyte, Figure 29 shows the general view of the apparatus.

The shaft was pinned at two centers and was put into rotating motion with a velocity of 30 - 40 RPM. Under each cam and bearing the surface of which requires tempering, tubes, the construction of which is shown in Figure 27, were installed at a distance of 20 - 30 mm.

The electrolyte reached the tubes from a common tank and was then collected in a catching basin from where it was pumped back into the tank.

Since the cam of the shaft has a protruding part, at that point, due to the shortening of the height of the jet and perhaps due to smaller heat losses the cam was heated to a higher temperature.

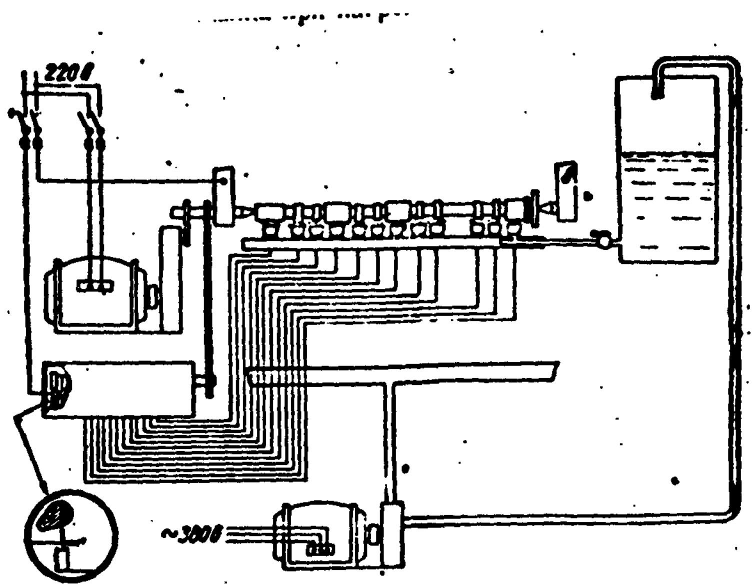


Fig. 28

Fig. 29

In order to eliminate the nonuniformity of the heating of the cam in one case a switch with a template was used which passed the current through another branch containing an additional resistance, when the protruding portion of the cam passed through the jet.

In another case the uniformity of heating of the cam was attained mechanically, namely, with a corresponding displacement of the tube and with the aid of a template.

See page 61a for Figure 29

Fig.29. General view of the laboratory apparatus for the tempering of cam shafts by heating in an electrolyte.

The latter version was used as a basis of a semi-automat which we developed for the tempering of cam shafts the general form of which is given in Fig. 30.

The tempering process in such an installation is realized in the following order:

1. The installation of the detail.

2. The switching in of the electrical motor for the rotation of

the detail.

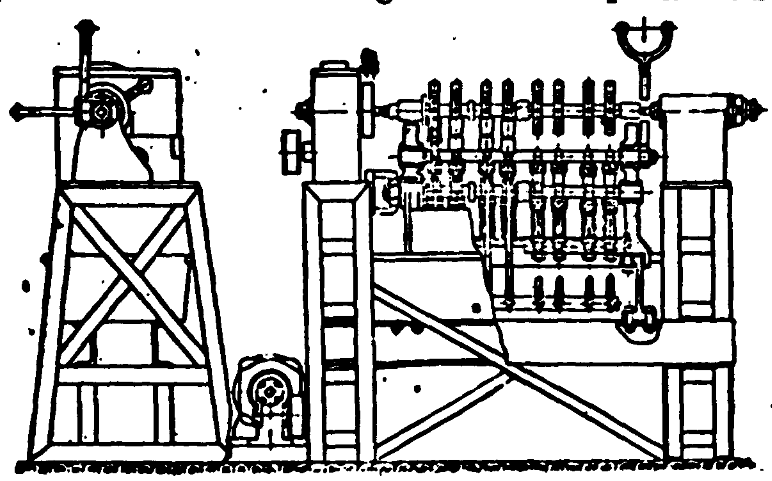
3. The switching in of the heating current (electrolyte from the tube flows continuously).

4. The disconnecting of the current and cooling of the detail (cooling is performed by the same electrolyte which, after the disconnection of the current can act as a cooling medium).

5. The disconnection of the electric motor and the removal of the detail.

In our experiments we employed a 10% solution of sodium hydroxide as our electrolyte.

For an electrolyte supply tube diameter of 12 mm the cam of the shaft is heated to a temperature of 850°C in 75 seconds, the bearings with a diameter of 55 mm - in 120 seconds. Here for the heating of one cam 7 kw are expended. As far as the heating temperature is concerned it can be controlled with an optical pyrometer and is bound to remain constant as long as the electrical regime of the operations is adhered to.



Semi-automat for the tempering of cam shafts

Fig. 30.

The regulating of the heating speed in the discribed method, aside from the previously mentioned procedures, namely, the changing of the electrolyte composition, current density, and others, can also be accomplished by changing the size of the jet and the rotating speed of the treated detail.

The conditions of selection of the steels for the details remain the same for the method of surface tempering by electroheating in an electrolyte as those for the other methods.

The results of tempering are characterized by the uniformity of the tempered layer; its gradual transition into the untempered core. Thus, for a cam shaft made of carbon steel designation 40, if tempered in accordance with the above discussed regime, a uniform layer of martensite with a depth of 0.7 - 0.9 mm is obtained followed by a zone of troosto-martensite and troosto-sobrite with a total depth of 2.5 - 3 mm.

The macrostructure of the tempered shaft is shown in Figs. 31 and 32.

On the experimental installation, built at XT3 in 1936, we processed a large group of distributing shafts of the motor STZ-NATI.

Fig. 31. Macrostructure of a cam shaft tempered after heating in an

electrolyte.

Wear resistance of cam shafts, tempered in an electrolyte, as shown by service data, does not differ from cementated shafts.

It should be pointed out that the method of local heating in an electrolyte jet can be successfully applied to details, the form of which permits one to concentrate the jet onto the spot to be heated.

Fig. 32. Macrostructure of a cam shaft tempered after heating in an electrolyte.

Difficulties arise with details where such concentration of the jet is hard to achieve. Thus, for example, when heating the bearings of crankshafts, when the electrolyte supply tube is located between the shaft faces the electrolyte is spilled onto these faces creating the necessity of increasing the power or leads to a decrease in current density at limited generator power.

For such cases the method of heating in contact with a porous fireproof insulator discussed below may turn out to be more effective.

It should also be pointed out that the method of heating in an electrolyte jet can be more effectively applied to details with small

or medium sized diameters. With an increase in the diameter of the heated part the same difficulties arise as with the first method where the heating was conducted during several revolutions, namely, the length of time required for heating as a result of significant heat losses.

HEATING IN CONTACT WITH A POROUS INSULATOR

Heating in contact with a porous insulator can be effective in application to details with complicated shapes in which the tempered areas must be exactly limited.

The basic scheme of this method is shown in Fig. 33.

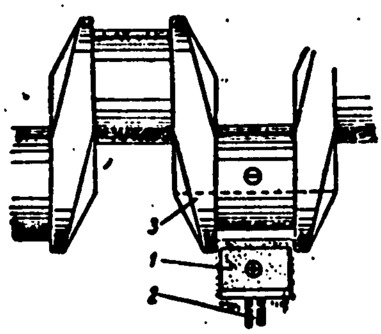


Fig. 33. The scheme of heating in contact with a porous insulator

The presence of porosity in the insulator ascertains its conductance when abundantly wetted by the electrolyte. Such an insulator must furthermore be fireproof.

After a number of studies the foam-chamotte brick was selected as such a material.

As can be seen from Fig. 33, the brick 1 is placed on a metal

support 2 which serves as an anode. The detail 3 is connected to the negative pole of the current. Brick is in contact with the detail at the spot which must be heated.

The surface of the brick can be shaped such as to be in contact with a larger or a smaller part of the detail.

Electrolyte, under some pressure, is supplied from below or above in such a way as to wet the surface of the brick. Heating takes place at the place of contact between the brick and the surface of the detail.

We limit our discussion here only to the basic aspects of the method, since the development of this method was started by us only recently and as yet is not sufficiently far advanced in details.

SEQUENTIAL HEATING OF METALS IN AN ELECTROLYTE

Further research by us for the purpose of developing methods of heating metals in an electrolyte have led to the development of the method of "sequential heating".

This method guarantees uniform heating of the details, having large surface areas, permits to realize surface heating and the heating along the entire section, local and total heating of the details and in this basically differs from all the other previously described

methods.

The significant advantage of this new method is the possibility of heating of large surfaces of the details and blanks and, at the same time, spending a relatively small amount of power.

THE BASIC SCHEME OF THE SEQUENTIAL HEATING

The method of sequential heating is based on the principle that part of the surface of the cathode which is immersed in the electrolyte can be shielded and protected from heating.

The basic scheme of the method of sequential heating is shown in Fig. 34.

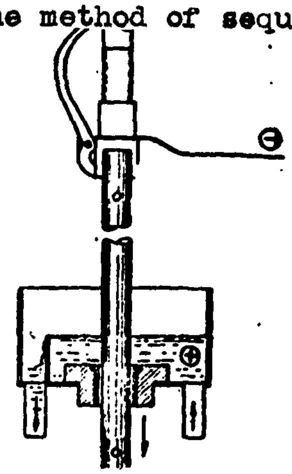


Fig. 34. The scheme of sequential heating in an electrolyte.

As can be seen from this scheme the bottom of the electrolyte container has mounted into it a fireproof brick bushing. The heated detail is attached to a negative terminal and can move up or down in the bushing. The design of the bath permits one to maintain the level of the electrolyte at a constant value, exactly in the same way as

the speed of heating, here we can in addition regulate by altering the electrolyte level in the container.

The expended power in the discussed method is determined by the surface area of the detail in contact with the electrolyte. It is perfectly clear that this power can be many times smaller than the power required for the simultaneous heating of the whole detail surface which is in contact with the electrolyte.

The temperature of heating in the method of sequential heating, all other conditions being the same, is determined by the speed of passage or the details through the layer of the electrolyte in the bath. With a decreased passage velocity of the detail the temperature of heating is increased.

Sequentail heating , as should be understood from the presented scheme, can be conducted during one passage of the detail through the electrolyte bath, or during several passages.

The latter method can turn out to be useful when it is desired that the speed of heating be smaller, or in the case of heating long, large diameter blanks, since here the possibility of cooling of the end, with which the heating process was started, is eliminated.

APPARATUS FOR CARRYING OUT THE SEQUENTIAL HEATING

in previously described installations for end heating.

It can be seen from the figure at any given instant only a part of the detail is in direct contact with the electrolyte (and consequently is heated). The surface of the detail which is located in the bushing, or below, is not being heated. In this manner, by moving the detail in the bushing one can apply sequential heating to a part, or the whole detail.

It should be pointed out that, as is shown in Fig. 34, one can instal a metallic bushing into the brick bushing; the former as a result will also be heated. When there is a clearance of the order of 1 - 2 mm between the detail and the bushing the electrolyte will not flow out of the bath. This can be explained by the forming of a gas and steam block. The possibility of efflux of the electrolyte at larger clearances between the detail and the bushing does not affect the process in relation to the shielding action of the insulator since the resulting flows of the electrolyte present a high resistance to the current. The magnitude of the clearance, as some experiments have shown affect the heating intensity somewhat.

From the presented principle of the method of sequential heating, aside from the previously discussed methods of regulating

The great variety of details which can be subjected to sequential heating, predetermine the various forms of apparatus required for carrying out this method. We present several examples which illustrate the apparatus for the sequential heating.

The scheme in Fig. 35 shows the apparatus for heating of rod - shaped details. In this case, depending on the shape of the cross - section of the detail, a shielding bushing with an anologous cross-section is furnished.

The heating of long blanks, particularly those of different forms of rolling stock can be usefully accomplished by way of conducting the blanks through several separately placed baths, or through several baths mounted in one "column", as is shown in the scheme of Fig. 35.

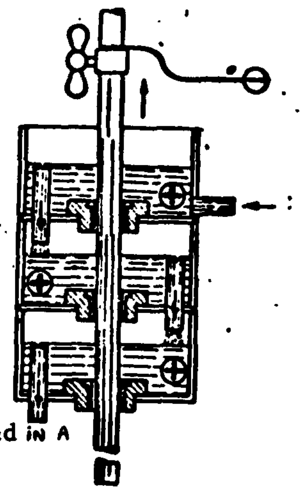


Fig. 35. The scheme of sequential heating in baths mounted in a "column".

It is necessary to stress that the principle illustrated by the scheme in Fig. 35 can be used for isothermal tempering.

In this case layers of electrolyte of different depths are placed into the baths computed such as to result in current densities requir-ed to sustain the heating and cooling regimes. By the same principle any thermal processing regime with regulated stages of heating, hold-ing and cooling can be employed.

Apparatus, consisting of several baths located in series, can also be of use in the case when it is important to increase the productivity of the corresponding installations by increasing the surface in contact with the electrolyte at any given time, i.e. by increasing power.

This condition is necessitated by the fact that a considerable in-crease in the electrolyte layer depth within the limits of one bath makes it difficult for gas formed on the cathode to escape to the sur-face and leads to bubbling and splashing of the electrolyte. Structur-ally this scheme can be built with very small distances between the layers of the fluid.

Fig. 34 shows that the heated detail at one end is attached to the negative terminal of the installation. Such connection of the details will satisfy many practical cases of heating of details and blanks. By the same method one can connect mandrels on which various details to be heated XXXXXXXXXXX and containing cavities can be placed (for example,

bushings, pins, pinions , and others). In sequential heating in an electrolyte the details can be supported between two centers as is shown in Fig.36.

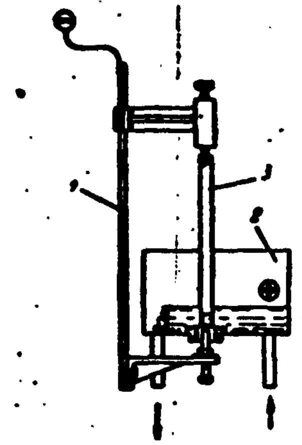


Fig. 36. Supporting of details between two centers during sequential heating in an electrolyte: 1 - support; 2 - electrolyte bath , 3 - detail.

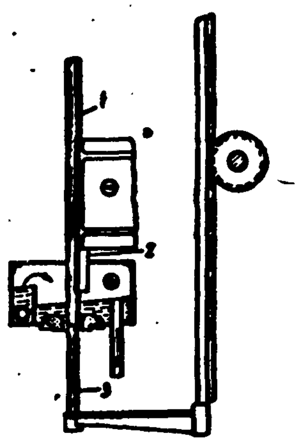


Fig. 37. Device with a sliding contact for sequential heating in an electrolyte.

The supporting of the detail between two centers permits the heating of the entire surface.

If it is necessary the upper center can be rigged to rotate which permits one to give a rotating motion to the detail during the heating process.

The installation of details in sequential heating can be achieved with the use of the sliding contact.

The scheme of such an installation is given in Fig. 37. Here the detail 1 is placed with one end onto a movable support 2 and with one of its sides rests on a fixed prism 3, which is connected to the negative pole. In this way the detail is displaced when support 2 moves and at the same time is fed by a current through the current conducting prism 3.

In such a procedure of mounting of the detail, as shown in Fig. 37, the current can be led not to the prism 3 but to the movable support 2. The prism in this case serves only as a guide for the details.

As was stated before, the method of sequential heating in an electrolyte permits one to achieve a local and a onesided heating of the details. Local heating, as can be easily seen, is attained by con-

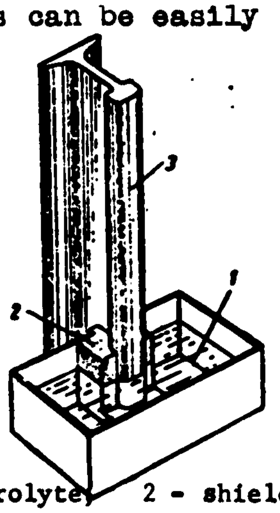


Fig. 38. The form of shielding (insulating) bushing for heating the top flange of a rail: 1 - electrolyte; 2 - shielding bushing; 3 - rail

necting the current only for the time interval when the part of the

detail to be heated passes through the electrolyte. For onesided heating the shielding bushing must be designed in such a way so that its shape would permit a contact between the detail and the electrolyte only from the side to be heated.

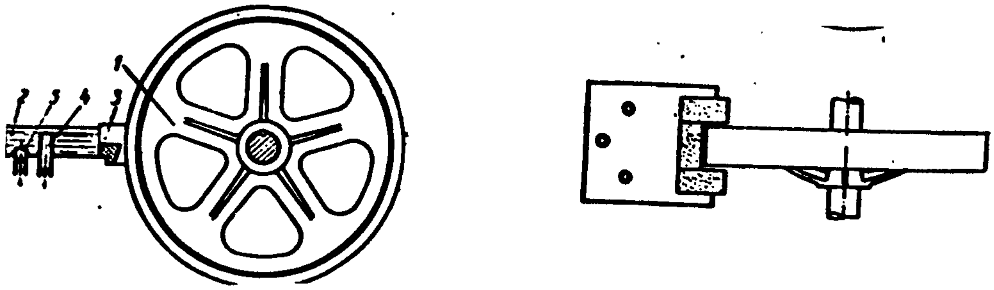


Fig. 39. Heating in an electrolyte of the rim of a support roller with the application of a shielding bushing: 1 - roller; 2 - electrolyte; 3 - shielding bushing; 4 - electrolyte withdrawal; 5 - electrolyte supply

As an example, Fig. 38 shows the form of a shielding bushing which can be used for heating of the top flange of a rail.

As can be seen from this figure, the edges of the bushing protrude above the level of the electrolyte and only in the section, which borders with the top flange a slit is made allowing the electrolyte to reach the surface to be heated.

Fig. 39 shows an analogous installation, developed for the tempering of the rim of a tractor suspension supporting roller.

From Figs. 38 and 39 it is seen that the construction of the bath

for onesided heating becomes a device which permits to create directional feeding of the electrolyte.

Of interest is the application of the method of sequential heating in an electrolyte for various processes of thermal treatment of metal sheets, belts, saws,discs, and other similar parts.

Aside from the stated advantages of the method of sequential heating in an electrolyte the application of this method for the mentioned parts can eliminate many technological problems, encountered during their processing by other methods.

As an example one can point out the difficulties during thermal processing of saws, knives,discs and other similar details in connection with warping. Great problems arise also when it is necessary to achieve local tempering of teeth and others.

Considerable difficulties are encountered during the thermal processing of duralumin and steel sheets when it is necessary to obtain a uniform and non-oxydizing heating, uniform tempering, etc.

For heating of sheets, belts, discs etc, we developed a method of sequential heating in which fireproof, insulating plates forming slits between each other can be used as shields.

Fig. 40 shows the scheme of such an installation.

As can be seen from this scheme the bottom of the container 1 has a slit to the edges of which are welded the interior walls of bath 2. Interior walls of the bath are made somewhat higher than the level of the electrolyte. To two lengthwise interior walls of the bath insulating plates 3 are attached forming between them a slit 1 - 2 mm in width greater than the width of the detail.

Insulating plates may take up only a part along the length of the basic slit of the bath, the remaining part can be used for the convenience of installing the heated details.

The detail 5 to be heated is attached to the terminal of the apparatus 4 and one of its ends is placed into the slit space of the bath.

In plates 3 and in corresponding places of the interior walls of the bath notches are made which allow the electrolyte to raach certain given areas of the detail where heating is to take place. Here also, as in previously described installations, the gas film, formed during heating arrests the efflux of the electrolyte through the slit.

It should be pointed out that in all cases the width of the notch in the insulating plates must be somewhat smaller than the width of the heated detail (by 1-2 mm) i.e., the end cross-sectional area of the detail must be covered by the shield. This is necessary in order

to decrease the current density in these places, and consequently to eliminate the overheating.

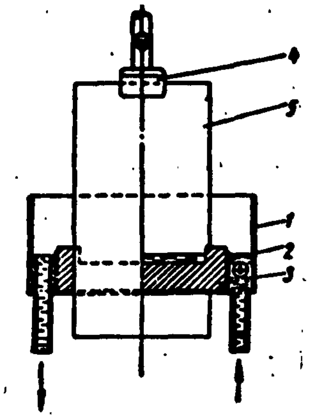


Fig. 40. Apparatus for heating of sheets, belts, discs and other analogous materials and designs.

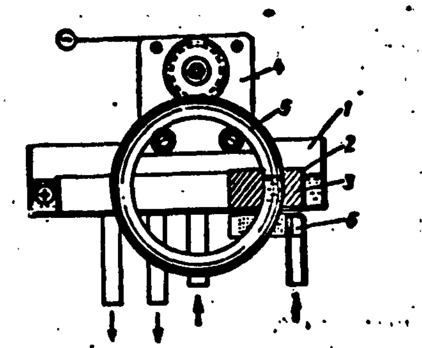


Fig. 41. Apparatus for sequential tempering of friction wheel rims 1 - bath; 2 - interior wall of the bath; 3 - shield; 4 - device for rotation of the disc; 5 - disc; 6 - shower arrangement.

Fig. 41 shows the scheme of the apparatus for sequential tempering of friction wheel rims. The bath for the electrolyte in this apparatus has the same construction as in the preceding case and differs only in the place of attachment of the insulating plates. Discs 5 have external teeth and are placed for heating onto two rollers of the device 4; they are geared with the guiding pinion. Discs, having interior teeth are placed directly onto the guiding pinion

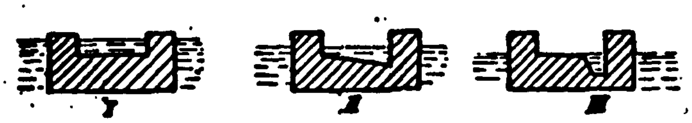
and are supported by two rollers from above (this case is not shown).

Insulating plates in the slit of the bath are located in such a manner that the disc, which is installed into the device 4, enters the slit between the plates only at one of its sectors. During the heating process the disc rotates at a given velocity and can be sequentially entirelly tempered in one complete revolution.

It should be pointed out here regarding the possibilities of obtaining full and uniform heating, local heating and onesided heating in the discussed installations.

The obtaining of the listed forms of heating can be achieved by altering the form of the notches in the insulating plates (see Fig. 42).

In scheme I (Fig. 42) the form of the notch is shown when its base is parallel to the level of the electrolyte. In that case the contact layer of the electrolyte is given at the whole length of the notch a constant depth. Such notch form assures uniform heating of sheets



I II III

Fig. 42. Notch forms in insulating plates.

or bands which are displaced with uniform speed in the vertical direction from above to below or from below to above.

For the rotating disc the displacement velocity of the different points of its surface varies and increases with an increase in diameter. Therefore, in this case in order to obtain uniform heating

the contacting layer of the electrolyte along the length of the notch must have various depths. This is obtained by designing the notch with a bevelled base.

The angle of the notch bevel is determined by the dimensions of the interior and the exterior diameters of the disc.

The plate with such a notch is shown in scheme II, Fig. 42.

For the case of local heating, for example the heating of only the teeth of the disc, or the teeth of the saw, a notch is designed as shown in scheme III, Fig. 42.

Such a notch form permits one to supply the electrolyte to the given sector.

For onesided heating the notch is made only in one of the two plates which form the slit.

The discussed principles of design of the apparatus for sequential heating allows the creation of most rational construction forms of the key production installations.

We can only mention that the material used for the shield does not necessarily have to be a nonconductor; semiconductors can also be emp-

loyed.

For example, the fireproof brick, used for this purpose, when saturated with the electrolyte becomes a semiconductor.

REGIME AND OPERATING CONDITIONS OF THE SEQUENTIAL HEATING

The works we have conducted for the installation of sequential heating for hot mechanical processing of blanks, in the first etape, included those with a section of up to 25 mm.

As was stated before, the sequential heating can be achieved during one passage, or during several passages through the electrolyte bath.

Table 9 gives the data regarding the heating of blanks with diameters of 12 and 22 mm during several moves of the traverse of the device carrying the blank; Table 10 - the analogous data for heating of blanks during one move of the traverse.

Comparison of the obtained data dealing with the heating of a number of blanks in oil ovens of blacksmith shops of ATZ with the data given in Tables 9 and 10, shows that one installation with heating in electrolyte , sized for a simultaneous heating of three or four details, in its productivity is equivalent to one oil burning oven of the slit type.

The feeling for the regimes and conditions of the sequential heating of details, made from sheet metal, can be obtained from the following data dealing with heating for tempering of strips and discs.

For strips 2.5 mm thick, 50 mm wide with a displacement velocity of 200 mm per minute and a voltage of 250 - 275 volts the required power is 8 - 10 kw. In the case of tempering of the friction wheel rim of the tractor STZ-NATI for a complete heating of up to 850° C at a rotation velocity of 0.6 - 0.8 RPM and a voltage of 250 - 275 Volts the expended power is 15 kw; if only the teeth were heated the power would be 7 kw.

The data given is applicable to heating of the strips from two sides and during one move and for the discs - for the heating of two sides during one revolution.

TABLE 9

Sample diameter in mm	Length of heated zone in mm	Depth of electrolyte layer in mm	Line voltage in network in volts	Working voltage in network in volts	Current in amps	Number of moves of traverse in one min.	Heating time to 1000-1100°C in sec
12	100	8	300	280	24	12	66
12	100	12,5	300	280	34	8	40
12	100	15	300	280	38	6	35
12	100	28	300	280	60—62	4	23
22	100	8	300	265	36—40	42	210
22	100	15	300	265	50	20	103
22	100	20	300	265	60—62	16	80
12	150	8	300	280	24	26	113
12	150	12,5	300	280	32	18	75
12	150	15	300	280	36	16	65
12	150	28	300	280	60	10	41
22	150	8	300	265	38	74	378
22	150	15	300	265	50	36	185
22	150	20	300	235.	60	28	144

It should be pointed out that during onetime (?) (onesided?) heating of the strips a bending occurs translator's note (of the sample) opposite to the heated side. The same sort of a bending occurs during heating of two sides if the heating intensity on the two sides is not equal. At equal heating intensities the warping of the strip can be made to equal zero. For this it is necessary to set up the bath and the notches in the insulating plates in such a manner as to obtain equal depths of electrolyte layers in contact with the surface of the detail.

Along with this, to eliminate warping, clamping devices which can ~~XXXXXXXXXX~~ stress the detail during the heating process, can be employed. The scheme of one of such clamping devices is shown in Fig. 43.

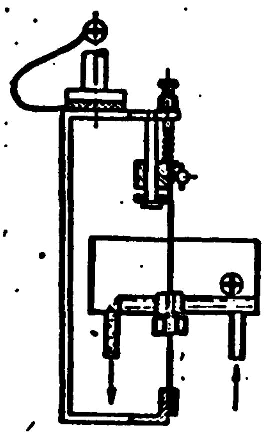


Fig. 43. Clamping device.

We investigated the warping of discs immediately after their local tempering (tempering of the teeth) to the maximum possible hardness for the steel designation 40 - 56 - 57 R_c. In this manner the discs tempered along the interior and exterior diameters do not change their form and the warping manifests itself in formation of a convexity in tangent planes.

TABLE 10

Sample diameter in mm	Depth of electrolyte layer in the bath in mm	Line voltage in volts	Working voltage in volts	Current in amps	Speed of displacement m/min	Heating temperature in ° C
						900
22	18	250	220	60	0,125	900
22	18	250	220	60	0,095	950
22	18	250	220	60	0,075	1000
22	18	275	245	65	0,125	950
22	18	275	245	65	0,095	1000
22	18	275	245	65	0,075	1050
22	18	300	270	70	0,125	1050
22	18	300	270	70	0,095	1100—1150
22	18	300	270	70	0,075	Melting of the surface
22	18	320	290	72	0,125	1250
22	18	320	290	72	0,095	Melting of the surface

Discs warped in such a manner are straightened out by riveting to the overlays made of raybestos. The proposed plan of further experiments envisages the elimination of this warping.

SURFACE TEMPERING DURING SEQUENTIAL HEATING IN AN ELECTROLYTE

Of considerable interest is the application of the method of se-

quential heating in an electrolyte for surface tempering of details.

The possibility of achieving surface tempering by the presented method is established by the fact that with an increase in the speed of the detail displacement through the electrolyte layer in the bath and with an increase in the current density the surface layer can be heated up to a temperature above the point Ac_1 to a given depth.

The tempering of the detail is attained by its cooling in the electrolyte, which, as is shown in Fig. 44, is achieved with the aid of a shower device located immediately below the insulating bushing 6 of the bath. Similar shower device, for the case of tempering of the supporting roller is shown in Fig. 26 and for the case of tempering of discs - in Fig. 41.

Experiments have shown, that for the application of the electrolyte as a cooling medium it is important that the potential of the electrolyte being fed into the shower device be somewhat lower than the potential of the electrolyte located in the bath. In that case there will be no electrical energy losses.

It should be pointed out that in principle it is possible to cool the details during tempering also in other mediums.

From the presented principle of surface tempering in an electro-

lyte , it can easily be seen that this method can be applied for a large nomenclature of details requiring surface hardening, like: various shafts, cutters , pinions , rails, etc.

As an example we present the conditions for conducting the process of surface tempering of tractor STZ - NATI pins , on which we conducted our experiments.

From experience, operation characteristics of tractors have shown that the reliability in performance of caterpillar links is sharply increased with the hardness of the pins.

Considering that each tractor requires 82 tracks, a corresponding number of pins and a great quantity of these details produced by plants as spare parts, in will become clear what a significance an improvement in the quality of these pins will have.

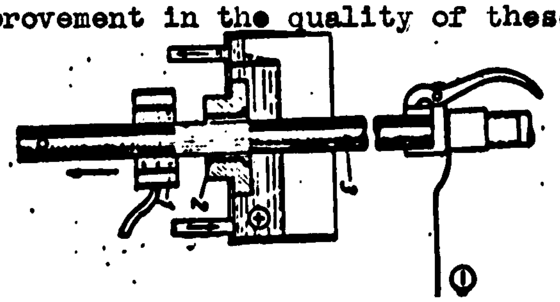


Fig. 44 Scheme of tempering of detail with a sequential cooling: 1 - shower device; 2 - insulating bushing; 3 - detail.

Track pins by existing technology are prepared from steel, designation 45, tempered and made for a hardness of 35 R_c.

In the process of thermal treatment of the pins a higher value of hardness leads to excessive brittleness, especially around cotter pin holes.

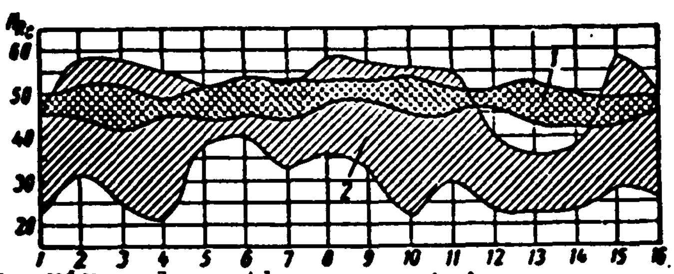
The elimination of brittleness of pins around cotter pin holes can be achieved by annealing the ends. However, the achievement of this process with present day technology of thermal processing for such a massproduced detail, like the track pin, presents great difficulties.

One should also point out such disadvantages of the existing process of thermal treatment of pins like their warping and the obtaining of ununiform hardness.

As is known, the reason for nonuniform tempering and weak temperability of carbon steels is their innate high critical speed of tempering.

All factors, lowering the critical speed of tempering favor the increase in the tempered depth and the obtaining of uniform hardness.

? →R_c



Spot of measuring along the generatrix

Fig. 45. Fields of distribution of hardness indecies for ordinary tempering 2 and for surface tempering with heating in an electrolyte 1 (measuring spots along the generatrix of track pins at 15 mm increments).

Carbon steels are tempered in water and rarely - in aqueous solutions of salts and bases.

The obtaining of a nonuniform (spotted) hardness is characteristic for water tempering due to the formation of a steam film which covers the surface of the detail and decreases the speed of cooling.

As is known, for the destruction of the steam film methods like intensive displacement of the details in the cooling medium, tempering by a shower, tempering in aqueous solutions of salts, etc., are employed.

However, all these methods are not sufficiently effective. Measurements of hardness, along the length of the pin, conducted by us on a whole series of samples, subjected to ordinary tempering and surface tempering during sequential heating in an electrolyte, yielded the results characterized in Fig. 45.

Data in Fig. 45, shows a large field of distribution, i.e. nonuniformity of surface hardness after ordinary volumetric tempering and

a hardness, almost stable, with minimal variations and high for sequential heating in an electrolyte. Uniform tempering of carbon steel, obtained during sequential heating in an electrolyte, is determined by the method of heating (sequential heating in a reducing medium), and also the cooling conditions - cooling with a salt solution (electrolyte) by means of a shower device.

During ordinary tempering of pins warping takes place, related to the cooling conditions and mainly to the nonuniformity of the results of the tempering. Surface tempering by the method of sequential heating in an electrolyte excludes warping almost completely.

Table 11 and Fig. 46 characterize the possibility of obtaining surface tempering to various depths, using heating in an electrolyte. Versions of tempering, answering to the requirement of a tempered layer of 3 - 5 mm on track pins (versions 2, 3, 6 and 7), are characterized by uniform and high hardness.

The macrostructure of the pins, subjected to surface tempering with heating in an electrolyte is given in Fig. 46.

Table 11

Versions of thermal treatment	Depth of electrolyte layer in mm	Traverse motion speed in m/min	Line voltage in volts	Working voltage in volts	Current in amps	Total depth of tempered layer in mm	Depth of martensite layer in mm	Hardness R_c	Load at failure (bending) in kg	Deflection in mm
1	28	0,20	300	255	69	1,4-2	0,4—1	39—40	2080	17
2	28	0,18	300	255	71	3—4	2—2,5	43—48	2900	13
3	28	0,17	300	255	73	4—4,7	3,2—3,7	43—45	2500	15
4	28	0,16	300	255	73	Tempering along thewhole section		50—52	1560	5
5	28	0,20	320	275	75	3—3,5	2	39—45	2000	12,5
6	28	0,18	320	275	76	4—4,2	2,4—2,8	50—54	2400	11
7	28	0,17	320	275	78	5—5,5	2,5—3,2	36—55	2540	10,5
8	28	0,16	320	275	80	Tempering along the whole section		40-50	1680	5
9[1]	—	—	—	—	—	—	—	10—31	2300	16
10[1]	—	—	—	—	—	—	—	16—46	2840	13

1/ Mechanical properties of track pins having been subjected to ordinary thermal treatment

Fig. 46. Macrostructure of track pins subjected to surface tempering during heating in an electrolyte.

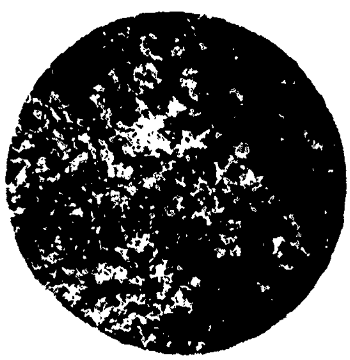


Fig. 47. Microstructure of the surface layer (at a depth of 1 mm) of a pin tempered with heating in an electrolyte, - small needle-shaped martensite

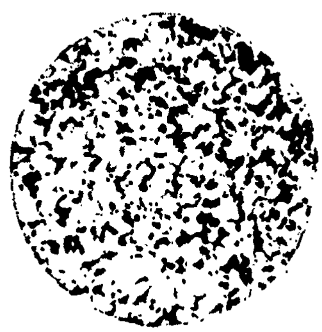


Fig. 48 Microstructure of the transient zone of surface tempered pins martensite + troostite.

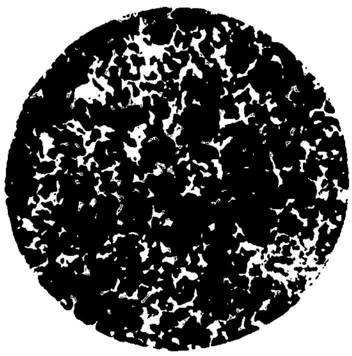


Fig. 49. Microstructure of the core of the pin, subjected to surface tempering with heating in an lelctrolyte, ferrite +

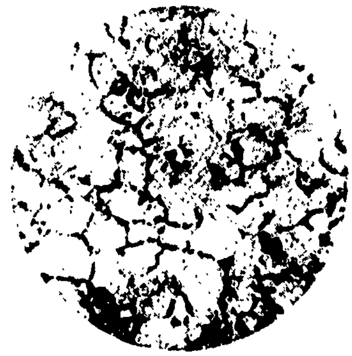


Fig. 50. Microstructure of the surface layer after ordinary tempering: martensite - troostite net.

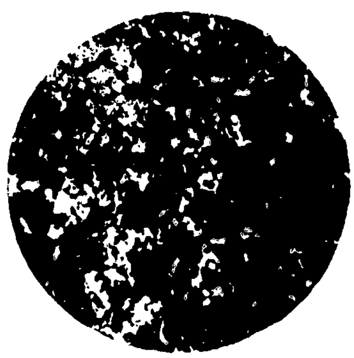


Fig. 51. Microstructure of the core of the pin, subjected to ordinary tempering, - troostite - sorbite+ferrite inclusions

Fig. 50. Microstructure of the surface layer after ordinary tempering: martensite - troostite net.

Fig. 51. Microstructure of the core of the pin, subjected to ordinary tempering, - troostite - sorbite + ferrite inclusions.

Microstructure of the surface of the tempered layer is characterized by the small-needle structure of the martensite (see Fig. 47), a gradual transition layer (troostite-martensite; troostite-martensite-ferrite(see Fig. 48)) to the core structure (ferrite-pearlite) (see Fig. 49.).

It should be pointed out that the structure of the surface layer of the pins, subjected to ordinary tempering (according to the existing process) at the depth of 1 mm, consists of martensite and troostite veins (see Fig. 50.) and has a hardness of $R_c = 56 \div 58$, and the structure of the core represents a mixture of troostite, sorbite and a small amount of ferrite (see Fig. 51).

It is not inappropriate to underline that during the surface tempering with the method of sequential heating in an electrolyte any oxydation of the metal surface is entirelly eliminated.

From the presented, it can be seen that the requirements given to the quality of track pins, can be satisfied by the process of surface tempering, since in this process a high surface hardness is attained with a maintaining of a ductile core.

The application for surface tempering of the method of sequential heating in an electrolyte simultaneously permits one to leave the ends of the pins untempered and by this to eliminate the necessity of using the process of annealing.

Surface tempering with the discussed method, as was pointed out before, almost entirelly eliminates the warping of the details.

As far as the productivity of the process is concerned, it can easily be seen from the presented data, it can be sufficiently large. The transmitting capability of one installation is designed for a simultaneous treatment of four track pins and amounts to 2500 units in 24 hours. The expended power for heating of one pin is ~ 15 kw.

In the investigation of all of these indecies one should also con-

sider the size of the heated detail surface. The heated surface for track pins is 276 cm^2.

From the presented data regarding the surface tempering of track pins one can easily see the great possibilities the given method of surface hardening of various details can present, especially in the replacement of the process of carburizing.

HEATING WITH A FIXED SHIELDED CATHODE

The method of heating with a fixed shielded cathode that we have developed can be realized by two versions. In the first version the fixed shielded cathode is permament and serves as an installing device for the heated details.

In the second version the fixed cathode is the detail itself, which is being heated and separate areas of which are protected from heating through the use of shields.

The basic scheme of the first version of this method is given in Fig. 52.

As can be seen from this ~~XXXXXX~~ scheme, the fixed cathode is attached to the bottom of the electrolyte bath through the shielding bushing.

In the electrolyte bath, like in all previously described installa-

tions, a constant level of the electrolyte is maintained and the depth of which can be regulated, through the use of a circulating system.

a)

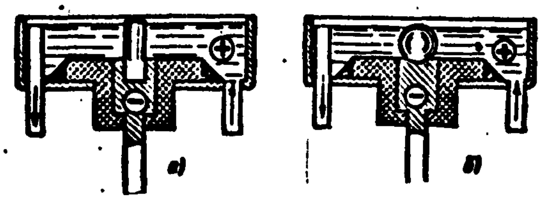


Fig. 52. Method of heating with a fixed shielded cathode:

1 - heating of cylindrical bodies; 2 - heating of a sphere

In such a device one can attain end or local heating of some details of a simple shape, for example, metal rods. In that case a nest is made in the fixed cathode as shown in the scheme and that part of the detail, which is not supposed to be heated, is inserted into it. The heated part of the detail however, must protrude above the cathode and must be wetted by the electrolyte. The fixed cathode must not protrude above the shielding bushing since in such a case the protruding part of the cathode will also be heated.

The protection of the end cross-sectional area of the detail from overheating and melting is attained by regulating the electrolyte level in the bath depending on the length of the heated end of the detail and by maintaining that level 1 - 2 mm below the end cross-section. In such manner the end cross-section of the detail is located outside the

zone of the heating effect of the cathode and is heated only due to thermal conductivity.

The first version of the method can also be applied for total heating of ball and roller bearings and other similar details. In this case a shallow socket is made in the end cross-section of the cathode into which the heated details can be self-positioned.

Using this principle we are developing at the present time automats for tempering of ball and roller bearings.

The principle of the second version of the method of heating with a fixed shielded cathode is illustrated by an example of its application in the tempering of disconnecting bearing body pins (detail of the tractor STZ-NATI).

The tempering of the disconnecting bearing body pins is ordinarily accomplished by heating them in lead baths. In this method of heating the body of the detail is also necessarily heated; this leads to its deformation.

The application of one of the previously discussed methods of end heating in an electrolyte for the tempering of such a detail also leads to difficulties. In this case the part of the pin adjacent to the body, due to high heat transfer is heated to a lower temperature than the

free end of the pin. As a result the pins are tempered only for a distance equal to 2/3 of their length. A deeper immersion of the detail into the electrolyte leads to an excessively high power consumption.

SEE PAGE 99a FOR FIGURE 53

Fig. 53. Device for heating in an electrolyte with a fixed shielded cathode.

Uniform and full tempering of the pins with an absence of deformations in the body was attained by the application of the method of heating in an electrolyte with a fixed shielded cathode.

Fig. 53 shows the scheme of the installation used for attaining the heating of this detail.

As can be seen from this scheme the heated detail 2 is placed into the attachment 1, which presses it against the shield 3, mounted into the bath bottom 4. The shield is designed (Fig. 54) in such a manner that during the installation of the detail its body is shielded and only the body pin and the plane of the barrel adjacent to the pin i.e. that part of the detail which is to be heated, protrudes above the shield.

The level of the electrolyte in the bath is kept at 2 - 3 mm below the end cross-sectional area of the heated pin, which, as was

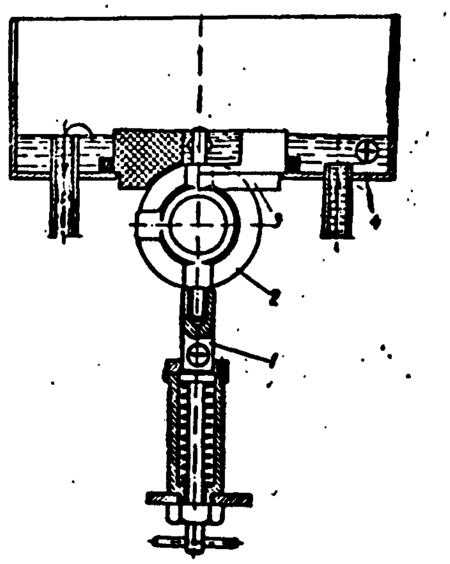


Fig. 53. Device for heating an electrolyte with a fixed shielded cathode .

pointed out before protects it from overheating. Negative pole is connected to the attachment 1 and the positive pole to the bath 4. After installation of the detail and the switching in of the current the heating process is started. After attaining the required temperature of heating the current is disconnected and the detail is subjected to tempering in an electrolyte.

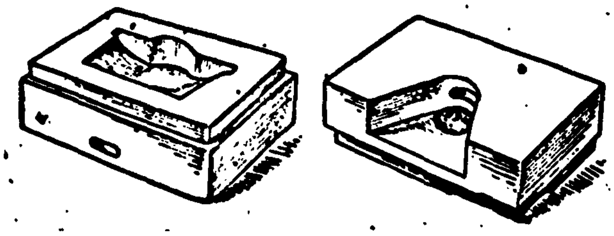


Fig. 54. Shield for heating of disconnecting bearing body pins coupling the tractor STZ-NATI

It should be pointed out that for all discussed devices for tempering of heated details the electrolyte can be used as the cooling medium. In the case when it is required that cooling of the details be carried out in another medium, prior to disconnecting the current, the electrolyte is let out of the bath. The latter can be accomplished by disconnecting the circulating pump or the use of a bath with a special drain valve.

Shields of complicated form can be most rationally made by forming a ceramic paste in special moulds followed by baking. In order to

increase the mechanical strength of the shields, one can impregnate them with various binding resins, particularly with a melted mixture of pitch and caoutchouc. This mixture can also be recommended for attaching of the shield to the bath.

CHAPTER III

CONSTRUCTION OF PRODUCTION INSTALLATIONS FOR HEATING IN AN ELECTROLYTE

1. GENERAL PRINCIPLES FOR CONSTRUCTING INSTALLATIONS FOR HEATING IN AN ELECTROLYTE

Production application of one or another method of electrical heating of metals becomes possible when one establishes the principles and rules which permit one to control the heating process and to attain its regulation.

Such principles and rules are established for the induction method, the electrocontact heating and the method of heating by means of an electro-resistance.

Thus, for example, it is known that the heating regime by induction of high frequency currents is determined by the current density, current frequency, heating time and the magnitude of the clearance between the heated surface and the inductor.

For the methods of electrocontact and electroresistive heating, the factors which affect the heating regime are the magnitude of the current density, the heating time and also the contact conditions.

For heating of a metal in an electrolyte such principles and rules have not been established prior to our work and on account of this this method did not find industrial applications.

The methods of heating of metals in an electrolyte which we have developed have permitted us to establish that the uniformity of the results is attained by the technological regime with a fixed composition and temperature of the electrolyte, the current density and the heating time. With this the accuracy of the installation of the heated detail and the quality of the contact are subject to rather simple requirements which permits one to use production installations of a simplified construction. This method of heating in an electrolyte differs favorably from the methods of electrocontact heating and the heating with high frequency currents which require high class accuracy and rigidity in the construction of their installations.

The necessity of such construction is brought about by the requirements of high accuracy of installation of the heated details during heating by high freqency currents and quality of the contact at the terminals and current conducting rollers during electrocontact heating method.

The installation for electrolytic heating of the metals consists of an electrical assembly - current source and the unit where the transfer of energy for heating of the detail is accomplished.

Here we will look only at the latter, i.e. the construction of the assembly - installations, where the heating of the details is performed, since the current source for the electrolytic heating does not have any special peculiarities and is widely known from application in other fields of technology.

ELECTROLYTIC BATHS

As has already been indicated, for various methods of heating of metals in an electrolyte, all other conditions being the same, the stability of the heating regime is achieved by placing in contact with the electrolyte of detail parts equal in surface and volume. This condition can be easily attained with the use of electrolytic baths connect-

ed to a circulating system and whose construction guarantees a constant electrolyte level.

Requirements which govern the composition and the temperature of the electrolyte, create the necessity of constant stirring; this is easily attained by the use of a circulating system. All these conditions determined the following basic principles for constructing electrolyte baths:

1. Electrolyte baths can be of a small volume and made of sheet metal.

2. Construction of the bath must allow for the possibility of regulating the electrolyte level; this is especially important for production facilities.

3. The circulating system consists of a reservoir tank, a pump and piping.

4. The capacity of the reservoir tank depends on the power for which the installation is designed. For installations designed for large expenditures of power and large productivity, the capacity of the reservoir tank can be decreased due to the application of a cooling system for the electrolyte. In such cases the electrolyte cooling system is also necessary for maintaining its temperature in the optimum interval.

The pump capacity,required for the circulating system, is determined separately for each automat type.

5. Circulating systems for electrolytic baths may be individual for each installation, or centralized, i.e. common for a group of installations. Individual circulating system can be mounted inside the installation or be taken outside of it.

6. In installations, designed for a large power consumption, the electrolytic baths must be connected to a forced draft ventilation system in order to remove electrolyte vapors.

THE INSTALLATION AND CLAMPING OF THE HEATED DETAILS

Construction of devices for clamping and installation of the heated details is determined by the principles of one or another of the methods on the basis of which the installation is constructed.

That condition, that for the clamping and installation of the details no complicated requirements are to be satisfied, makes the problem of creating universal installations somewhat easier.

Thus, for example, for the method of "end heating with shielded end cross-sectional areas" the universality of the installation is achieved by the use of magnetic clamps or interchangable mechanical clamps,

the introduction of the clamp lóocation regulating and the regulation of the depth of immersion of the details into the electrolyte.

It should be remembered, that the simplicity of construction of the devices for attaching the details(contacts) is explained by the fact that the heating in an electrolyte is related with an increase in the voltage. Thanks to this situation even when a high power is used the current through the detail has a relatively small value.
The construction of the contacts (clamps), as is known, becomes more complicated, when designed for a large current. For a large current it is important that the contact be attained over a large area and at a given pressure. The complexity of making contacts for a high current puts limitations on the application of the electrocontact heating method and the electroresistive method of heating, since they depend on the use of high currents at a low voltage.

INSULATION OF POLES AND SEPARATE KEY MECHANISMS

In the electrolytic heating installations one must electrically insulate the electrolyte baths and the components of the circulating system which are given a positive potential, clamping devices which are given a negative potential and separate key mechanisms which

are coupled to the devices of clamping and installation of the details, or connected to the electrolyte bath.

It should be pointed out that if one of the poles of the current source is grounded units and assemblies having the same potential can also be grounded. However, for a greater guarantee from possible shorts in the production facilities we have developed both poles are insulated.

Starting out from the requirement that separate units and assemblies must be insulated, we must consider the elimination of electrolyte leaks and other factors capable of ruining the insulation in the construction of the installations.

From the same considerations the insulation of the poles should be performed outside the limits of the electrolyte leaks, splashing, or areas of high electrolyte evaporation.

The insulation places should be protected with blankets, shields and other similar methods.

In places where there is a possibility of the action of the discussed factors, serving to break up the quality of the insulation, one should use high voltage porcelain insulators. The type of these insulators is selected on the basis of the necessary conditions of attaching the units and other structural considerations. In protected places and in case it be-

comes necessary to achieve insulation through the making of mechanism details from insulating materials, depending upon the operating conditions of these details and the stresses they are subjected to, materials such as textolite, ebonite, gitenax, etc, may be employed.

MECHANISMS AND AUTOMATIC DEVICES

The maximum possible mechanization and automation of the process of heating metals is the most progressive step in the development of technology not only from the point of view of increasing production and an improvement in the working conditions, but also because it eliminates subjective factors, related to the qualification of operators and affecting the quality of treatment. Mechanization and automation are most easily adapted to induction heating methods and to methods of heating of metals in an electrolyte.

The construction and preparation of mechanisms and automatic devices for installations of electrolytic heating are very much simplified due to previously described conditions related to the installation and clamping of the heated details, and because the details during heating are not subjected to the effect of any action of any stresses. These considerations eliminate the use of primitive installations and,

on the contrary, dictate the usefulness of construction of mechanized and automated installations.

As could be seen from the described methods of heating, the mechanisms of the installations, starting out from the conditions of one, or another of the methods, must achieve various forms of displacement, or movement of the details.

In many cases motion, or displacement of the details must be conducted with a definite velocity. The possibility of regulating the velocity of motion, or displacement, within the limits of one installation, of the treated detail and to alter the velocity of displacement indicates the universality of the installation. The principles of constructing of mechanisms in accordance with these conditions are manifold and are similar to the principles employed in the construction of metal machining lathes and devices.

The peculiarities of mechanisms of the installations of electrolytic heating are such that they are designed for low velocities, small stresses and include some of the elements of electrical machines.

These peculiarities simplify the construction of installations in which all the operations, starting with the loading of the details and their removal can be entirelly automated.

For regulation and automation of the installations , one can to a considerable degree utilize electrical apparatus which is widely used in the machine construction field.

SAFETY TECHNOLOGY

In order to guarantee conditions of safety technology for the installations of heating of metals in an electrolyte one must enclose them in metal laggings which are attached to the frame, or the base of the installation and do not touch current carrying units or details. The lagging, as well as the frame, or base installations are grounded.

In installations where all the operations are automated it becomes possible to enclose the entire assembly by the lagging and to perform the loading through a bunker, or another similar device, insulated from current carrying parts.

Installations which do not have devices for automatic loading of the details, where the places for clamping the details must remain exposed, must be furnished with signaling. In many cases such installations can also be furnished with covers, which are connected to the mechanism in such a manner as to bar access to current carrying parts when the current is flowing.

Working conditions of electrolytic heating installations have shown

that in production conditions, the listed measures entirelly guarantee the safety of work.

2. CONSTRUCTION OF AUTOMATS FOR HEATING IN AN ELECTROLYTE.

The discussed principles of construction of production facilities for heating of metals in an electrolyte do not encompass all the heating methods we have developed and refer mainly to the methods which have received application in industry.

Below we describe only some of the constructions of production installations which we have developed and which can serve as an illustration to the presented principles of the construction of such installations.

AUTOMAT OF THE TYPE AE-1

First production facility was constructed on the principle of the first of the previously discussed methods of end heating and installed in HTZ in 1937. for the tempering of ends of intake and exhaust valves of engines.

The automat consists of electrolyte baths, with a circulating system, installing and clamping device, displacement mechanism for details

and appliances which achieve automation.

All these basic units of the automat (Fig. 55) are mounted on a metal table built of steel angles and plates. Electrolyte bath 1, which is constructed from sheet metal, is installed on porcelain insulators and attached to the upper plate of the table.

In order to protect the bath from the current it is enclosed by a wood lagging. As was already pointed out, in order to obtain uniform heating it becomes important to maintain a constant electrolyte temperature and stability of its level in the bath. These conditions are attained with

See next page

Fig. 55. Scheme of the automat AE - 1

the following circulating system. The electrolyte is conducted through a rubber hose 3 into the bath from a supply tank 2, which is mounted on a special frame which in turn is attached to the table plate. The bath has a overflow pipe 4 through which the excesses of the incoming electrolyte are pumped with a gear drive pump 5 back into the supply tank.

The upper metal plate of the table has two guides 6, along which the cantilever 7 can be displaced. The cantilever carries the clamping device

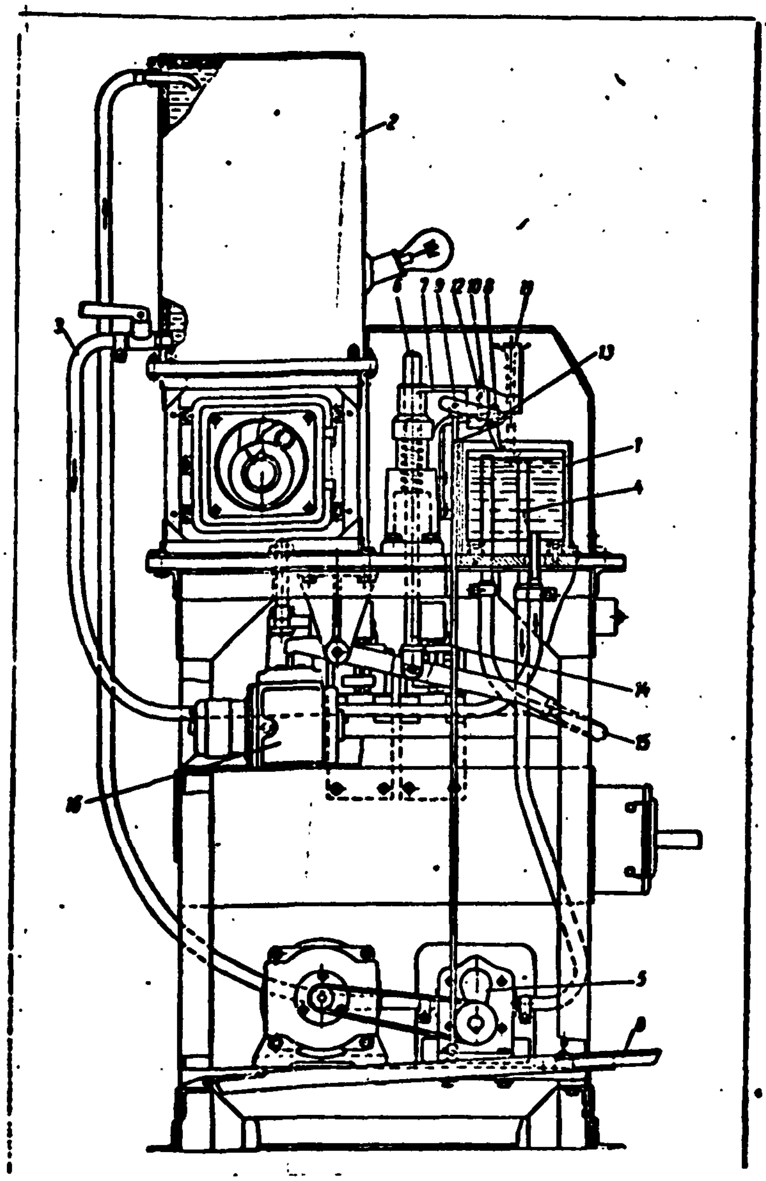


Fig. 55. Scheme of the automat AE - 1

which is attached to it and insulated from it with an ebonite gasket. The clamping device is located above the electrolyte bath.

The construction of the clamping device permits a simultaneous positioning at the required height of several details. The installation of details into the clamping device is accomplished in the following manner: by pressing down the foot pedal 8 one rotates the clamping device shaft 10 through an interconnecting lever 9; during this, small levers which are welded to the shaft remove the clamps and open windows in which at the required height the treated details 11 are placed. Then the pedal is released and the clamps, activated by springs, grab the details. The immersion of the details into the electrolyte for an equal depth in this automat is accomplished with a special installing device.

The version of the installing device is accomplished in the form of brackets 12 attached to the shaft 13. The brackets, with the aid of a template ruler, are installed underneath the details when the cantilever with the clamping device is in its uppermost position and move aside when the cantilever is lowered. The movements of the cantilever 7 up and down along the guides 6, and consequently the displacements of the details, are achieved by a coupling rod with a spring 14, the lever 15 and the reducing gear 16.

The scheme of the automat is given in Fig. 56. From the scheme it can be seen that automation of the installation is brought about by a time relay. The body of the clamping device A is attached to the negative DC terminal and the electrolyte bath B to the positive. By pressing the double push button K one turns on the reducing gear electrical motor M_1 with a relay contact K_1 and thereby achieves the interlocking between the time relay disc and the constantly rotating synchronous motor.

After the reducing gear coupling rod moves out, and consequently, due to the displacements of the lever 15 and the coupling rod 14, details are immersed into the electrolyte, the reducing gear electrical motor is disconnected with a special contact installed on the reducing gear. When the time, required for attaining the necessary heating temperature of the details, has expired, the contact disc of the time relay closes the reducing gear electrical motor loop and opens the time relay and DC loops.

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Fig. 56. The electrical scheme of the automat AE - 1.

This leads to the raising of the details out of the electrolyte bath and

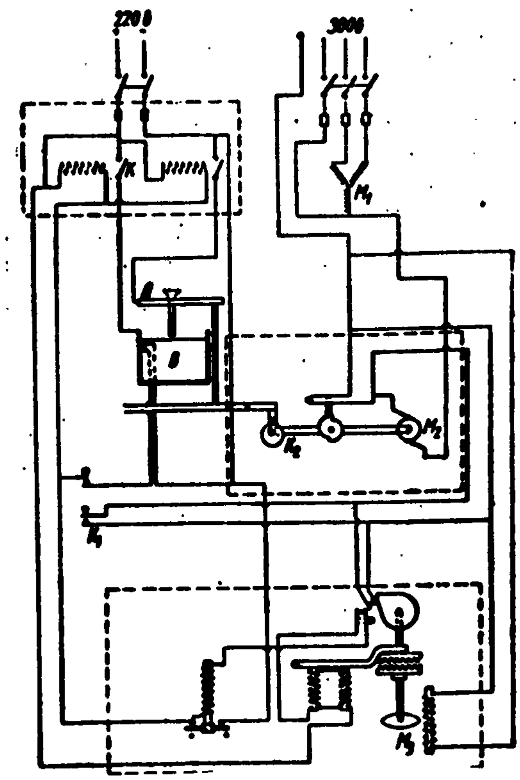


Fig. 56. The Electrical scheme of the automat AE - 1

subsequential disconnection of the contact.

In this manner the order of operations in the automat in the second version of the installing device consists of the following:

1. The foot pedal is pressed and the details are installed into the windows of the clamping device.

2. With the pedal held, push button K is pressed and the automat is switched on.

3. After the end of the working cycle, which is indicated by a light signal, the pedal is pressed for the removal of heated parts and the installation of new ones.

The heating temperature of the details, as can be seen from the scheme, is easily regulated by the setting of the time relay contact, i.e., changing of the heating time. Construction of the automat permits also the changing of the length of the tempered end of the detail by the regulation of the electrolyte level height.

This regulating is attained by raising or lowering of the electrolyte bath overflow pipe. The productivity of the discussed automat equals 400 details per hour.

AUTOMAT OF THE TYPE AE - 2

Automat of the type AE - 2 was developed by us and installed at HTZ

in 1940. Basically it also uses the first method of end heating - "heating of the free end". This type of an automat permits, without any special adjustments, the treatment of details of several forms and to completely automate all the processing operations.

The scheme of the automat is given in Fig. 57. As can be seen from the scheme, the heated detail 6 is installed on the shelf 3 of the receiving plate 2. Shelf 3, is automatically, with the aid of a system of cams, removed at a specified moment and the detail drops along a groove of the receiving plate into the receiver of the clamping device, or the carrying drum.

The clamping device represents a drum, consisting of the shaft 4 in which five plates are attached at an angle of 72°. To each plate of the drum a shaft 's attached on which clamping levers 5 are sitting. Lowering of the levers (clamping of the details) is accomplished with the aid of springs attached at their ends.

The carrying drum is rotating on its shaft in bearings pressed into the body of the apparatus, which consists of two textolite plates drawn together with tacks.

The rotation of the carrying drum caused by the leading shaft is accomplished by means of a driven disc, fitted on the end of the drum

axle; this disc has five fingers attached at equal spaces and the leading shaft has a cam fitted onto it. The leading shaft, similarly to the drum shaft rotates in bearings pressed into the body of the apparatus and is made to rotate by an electric DC motor 17 and the reducing gear 16 through the transmission 18. Such transmission of motion to the carrying drum permits for one rotation of the leading shaft, during the period of the interlocking of its cam with the finger of the driven disc of the drum, to rotate the drum for 72° and thereafter, for a given period of time to fix its position. With this the length of the drum stops is determined by the speed of rotation of the leading shaft.

The scheme (see Fig. 57) shows the layout of the drum plates at the time of a stop. The direction of one of the plates of the drum here co-

See next page

Fig. 57. Scheme of the automat AE - 2.

incides with the direction of the grooves of the receiving plate and one plate (fourth) in the counterclockwise direction assumes a strictly vertical orientation.

The electrolyte bath 7 is installed below the drum. The bath is locat-

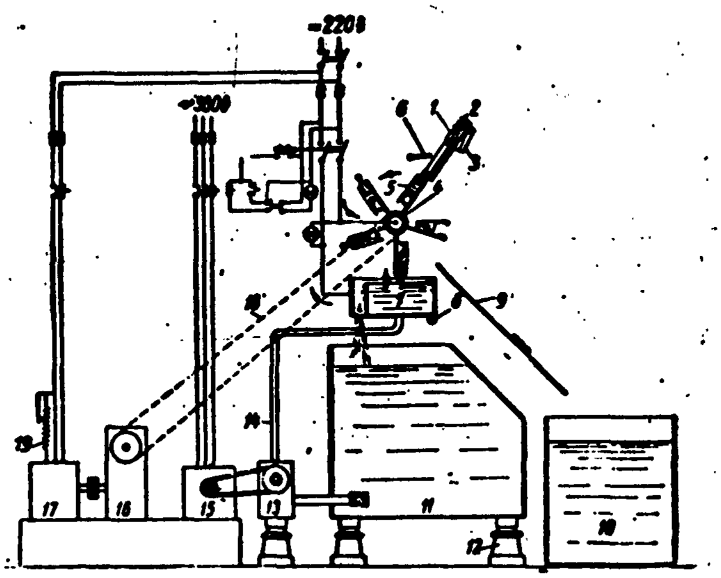


Fig. 57. Scheme of the automat AE-2

ed in such a manner that the ends of the details are immersed into the electrolyte when the plate of the drum, to which they are clamped assumes the vertical position. The drum is connected to the negative DC terminal through a special contact and the electrolyte bath to the positive pole.

Before describing the order of operations of the automat it is necessary to point out the layout of a presser (installing device).

The presser 6 consists of a shaft supported by bearings which are pressed into the body of the instrument. Teeth are welded to the shaft in one plane. The presser shaft is located in such a manner that during its rotation each of the teeth welded to it presses on the end cross-sectional area of the detail. The detail is clamped in the carrying drum (clamping device) and is pressed down further to a predetermined depth.

The order of operations in the automat are as follows: in the moment when the drum is fixed in one of its positions the clamping levers on the plate which has approached the receiving plate , are raised; heating process of the details which are clamped to the drum plate, located in the vertical position at that time, is triggered. In the next moment the shelf of the receiving plate is removed and new details fall into the drum. Then follows the clamping of the new details (the clamping levers are lowered) and

the raising of the levers on the plate which has passed through the vertical position, i.e. the expulsion of the heated detail.

After the end of the detail heating cycle, the drum rotates through 72° and the described process starts all over again.

Heated details fall along the guiding groove 9 into tank 10, containing the cooling medium.

The obtaining of uniform heating of the details in this automat is guaranteed by the maintainance of a constant electrolyte level and temperature, required in addition to the satisfaction of the clamping requirements discussed above. The former are achieved with a circulating system and a special construction of the bath.

With the aid of the pump 13 and the piping 14 the electrolyte is transferred to the bath 7 from the basic reservoir 11 which is sitting on an insulator 12. Excess electrolyte flows over a partition in the bath and through an orifice in the bottom of the tank,on the other side of the partition, back into the basic reservoir 11. Bath 7, on one side, is attached to hinged insulators and on the other side to similar insulators on screws.

Such attachment of the bath permits one to alter the height of the electrolyte level with respect to the drum and, consequently, the depth

of immersion of the details.

Regulation of the heating speed, similarly to that in the automat of AE - 1 type, can be achieved by changing the composition of the electrolyte or the voltage. All other conditions being equal, the heating temperature is determined by the heating time, i.e. the stop duration of the drum.

As was pointed out before , the stop duration of the drum depends upon the rotational velocity of the leading shaft. The application of a DC electrical motor for the rotation of the shaft, permits one to change the speed of rotation by changing the resistance of the shunt winding of the motor.

As can be seen from Fig. 57, the electrical scheme of the automat is very simple. The turning on of the automat is accomplished with the aid of push buttons.

As can be seen from Fig. 58, the automat is entirelly enclosed by a lagging. The only open area is a part of the receiving plate, i.e. the place for loading of the details. In the rear side of the lagging there is also a slit for removal of heated details.

The automat constructed at HTZ was designed for the treatment of details like regulating screws of an engine, thrust screws of an engine, or

pivot journals.

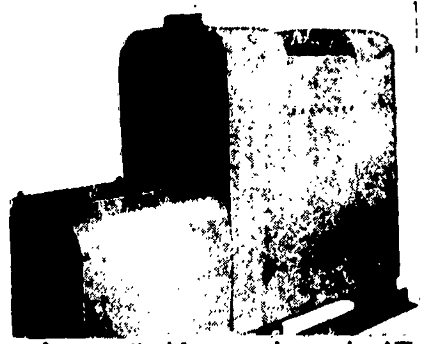


Fig. 58. Exterior view of the automat AE - 2.

This automat is also used for annealing of ends of rods.

Duration of heating of one detail is 8 - 10 seconds; simultaneous treatment of eight details can be conducted. The productivity of 2000 details per hour can be attained.

AUTOMAT OF THE TYPE AE - 4

During the development of the construction of the first production installation, based on the principle of the end heating method with shielded end cross-sectional areas (automat of the type AE - 4), the system of cyclical action was employed based on the required conditions of productivity (300 - 400 details per hour). This automat is to a sufficient degree universal.

In order to introduce the new method in industry in the shortest possible time period, it was , for the time being, necessary to refrain from using a number of improvements in construction which would have led to complications in the preparation of the installations.

Automat of the type AE - 4, like the very method,was developed and installed in a number of plants of the Soviet Union in 1944 - 1946.

In order to further implant the automatic electroheating of metals in an electrolyte this automat type was mass produced by the Altai tractor plant, named after Kalinin; the automats were used by plants and scientific research institutes.

Figs. 59, 60 and 61 show the schemes of the automat and Fig. 62 its general view. Fig. 59 shows a whole list of almost identical units to the previously described automat AE - 1. The electrolyte bath 1, supply

See page 127 for Figure 59

Fig. 59. The scheme of the automat AE - 4.

tank 2, and the remainder of the circulating system differ in this installation only by the layout which make this installation more compact and better protected from current carrying parts and possible leaks of the solution. In principle the scheme of raising and lowering of the details from and into the electrolyte does not differ much either. The cantilever 4, carrying a special suspender moves in the guides 3. Displacements of the cantilever 4 are brought about by the raising and lowering of the le-

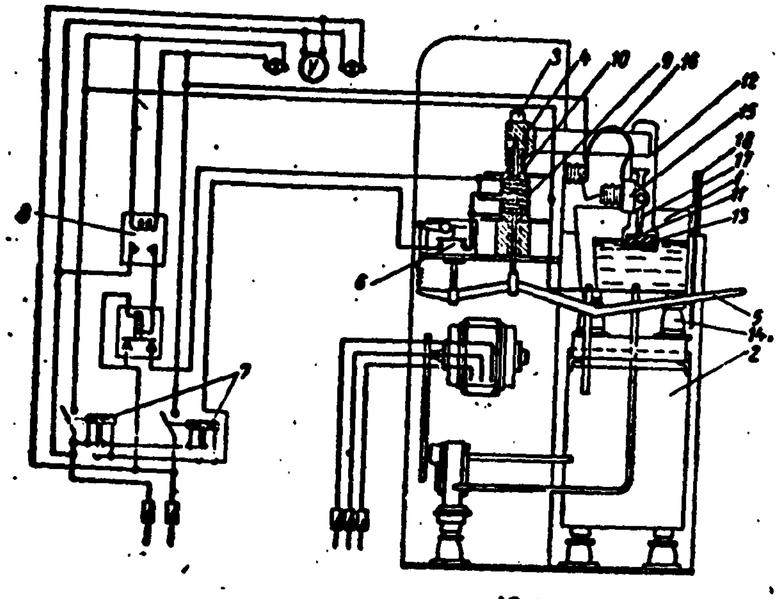


Fig 59. The Scheme of the automat AE-4

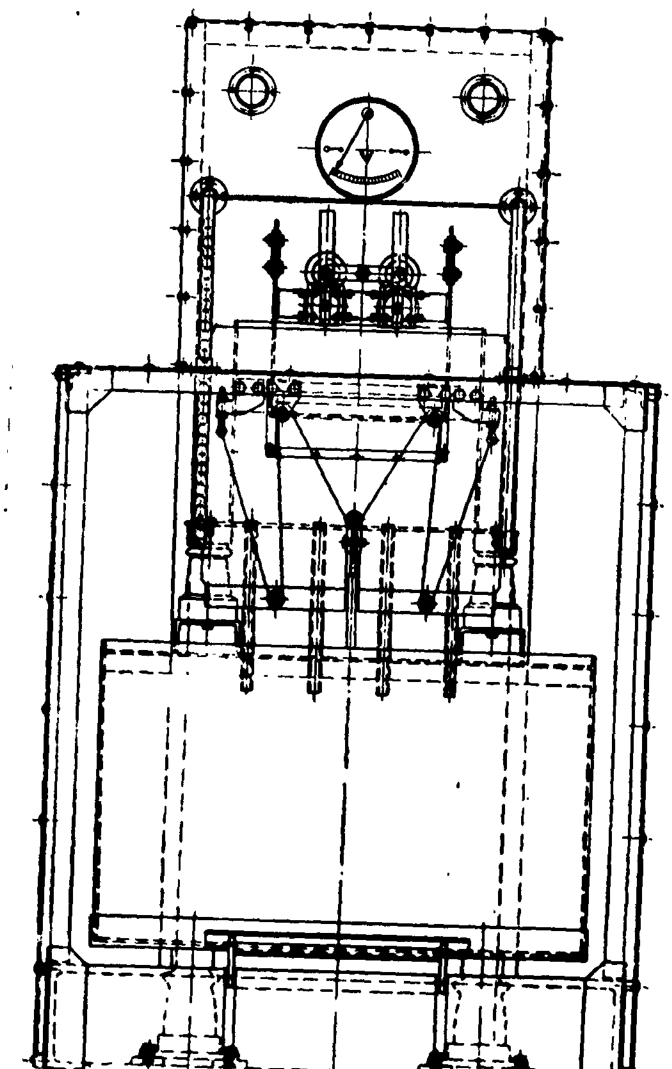


Fig. 60. General front view of the automat AE-4

ver 5. Contactor coil 7 and time relay 8 are simultaneously switched on through contact 6 when the lever 5 is lowered; the contactor closes the loop of the electromagnet 9 and the cantilever, carrying the heated details is supported for a given period of time. By switching on the con-

See page 127

Fig. 60. General front view of the automat AE - 4.

tactor the current to the electrolyte bath and the heated detail is also turned on. At the end of the set heating time period, the time relay stops operating, opens the electromagnet loop and the cantilever with the suspender is displaced upwards by the springs 10.

See page 129

Fig. 61 General side view of the automat AE - 4.

See page 130

Fig. 62. Exterior view of the automat AE - 4.

The installation differs significantly in the suspension device of

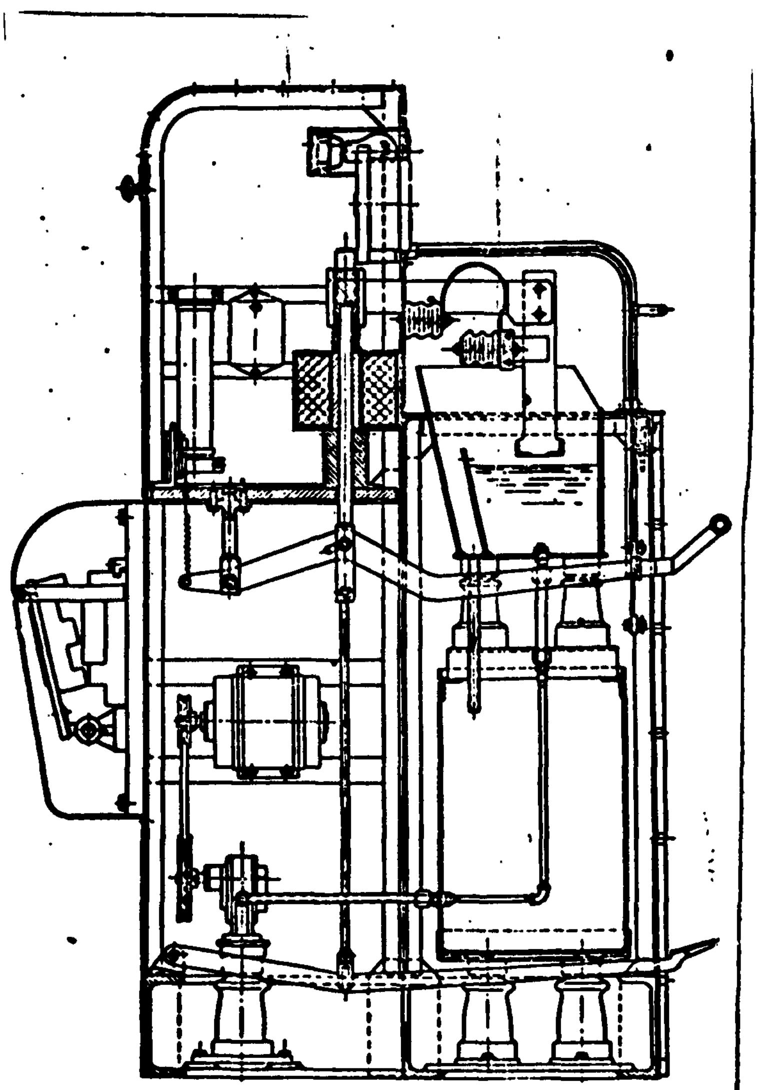


Fig. 61. General side view of the automat AE - 4.

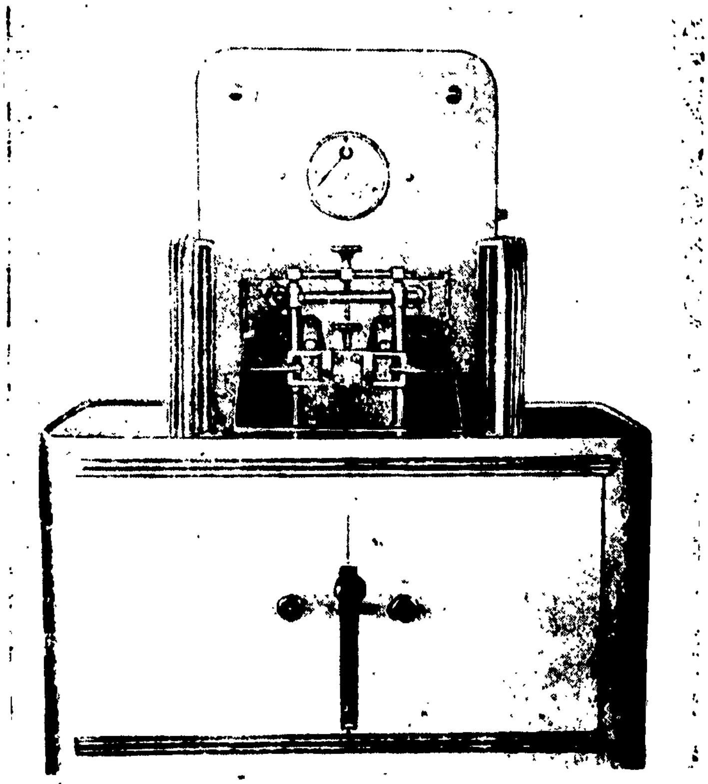


Fig. 62. Exterior view of the automat AE-4

its carrying detail. The base of the suspension is a metal box 11, which is connected through two flanges 12 and insulating washers with the cantilever 4. A fireproof brick 13 is placed into the metal box of the suspension. Perpendicular to the brick, to flanges of the suspension, permanent magnets, or mechanical clamps 15 are attached to tops of ribbed insulators 14. Negative DC terminal is connected to these magnets or clamps via a pack of copper foil 16.

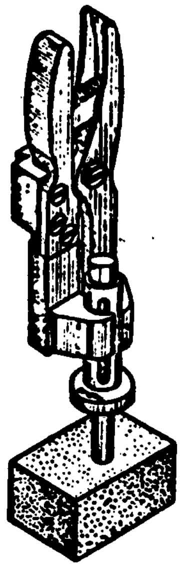
In such a manner, heated details, or blanks 17 are placed with their end cross-sectional areas onto the brick and are held in place by permanent magnets or the mechanical clamps, through which the current flows.

Details to be heated are lowered into the electrolyte together with the whole suspension and are also raised in the same way.

See page 132 for Figs. 63, 64, 65,

Fig. 64. Clamp for rodlike details.

Fig. 65. Clamp for valves.



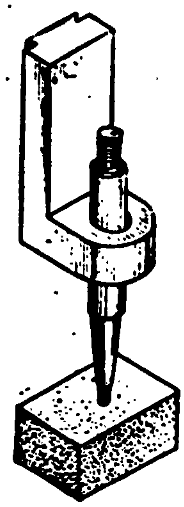
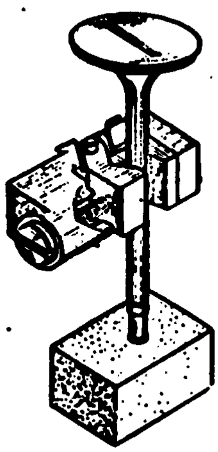


Fig. 63. Pincer clamp.

Fig. 64, Clamp for rodlike details



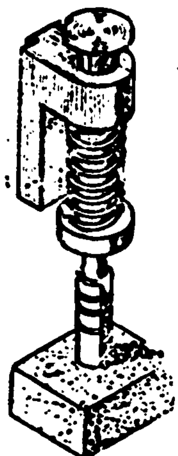


Fig. 65. Clamp for valves

Fig, 66, Clamp for short details

See page 132 for Fig. 66

Fig. 66. Clamp for short details.

It is clearly understood that the described construction of the suspension also satisfies the requirements related to equal immersion depth of the details into the electrolyte.

The suspension board with the clamps 15 and the metal box 11 with the brick 13 can be lowered or raised within special guides with the aid of screws. This permits the regulating of the immersion depth of the details into the electrolyte, and consequently the length of the heated part of the details.

An additional detail of the installation should be pointed out - the protective shield 18 which automatically raises, closing the electrolyte bath during the immersion of the details and then is lowered during the removal of the details , i.e. the end of the heating cycle. This protects the operator from ill effects of the light produced during heating.

The operating cycle on the installation consists of the following operations:

1. The attachment of the details, or blanks into the clamps with the placement of the end cross-sectional areas onto the brick of the suspension.

2. The lowering of the handle 5 to a rest.

3. The removal of the details at the end of the heating cycle.

Figs. 63 - 66 show examples of interchangable mechanical clamps used for automats of the type AE - 4.

As can be seen from these diagrams, the clamps have dovetails, with which they are installed in corresponding nests of the suspension. Such clamp attachment simplifies the interchanging during the readjustments of the automat for the processing of other details.

Fig. 63 shows a clamp which has the form of pincers.Such clamps are convenient when there is a necessity of moving the details after heating into a cooling medium.

The form of the clamp shown in Fig. 64., is used for many rod type details, the removal of which can be conducted by hand.

The clamp shown in Fig. 65., can be used in connection with a mechanical knock-off. The clamp (Fig. 66) is applied for various details and permits the attainment of not only of an end heating, but the heating of the whole surface of the detail.

AUTOMAT OF THE TYPE AE - 5

Automat of the type AE - 5, like the previous type, is designed for various purposes of heating of the ends of details and blanks.

This automat type is intended for a production of 600 - 800 details per hour and is constructed on the principle of continuous action.

The scheme of the automat is shown in Fig. 67 and the exterior view in Fig. 68.

As can be seen from Fig. 67, automat AE - 5 is of the carousel type. The supply tank 1, electrolyte bath 2 and the pump 3 with the piping, which make up the circulating system of the installation, are located in the lower part. Middle part of the installation consists of a drum 4 which carries the suspenders and the upper part contains the drum drive 5.

The drum of the installation consists of two textolite discs 6, tied together by guiding bushings 7 and a boss 8 which forms the rim of a special ball bearing fitted on a hollow axle 9. The drum is connected to the drive through pinions 10 and 11 and can rotate around the axle 9. Coupling rods 12 can move inside the guiding bushings of the drum. A suspender is attached to each two coupling rods, this includes the clamping and installing devices. All in all, ten suspenders fit on the drum.

Like in the case of automat AE - 4, on the suspender cantilever 13 there

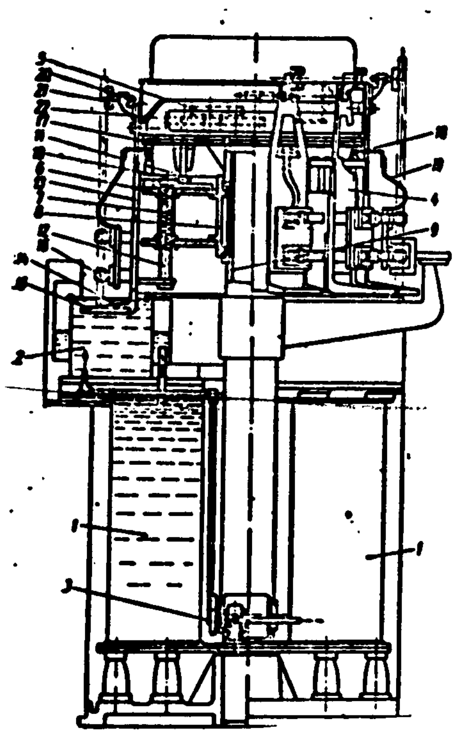


Fig. 67. Scheme of the automat AE-5.

is a metal box 14.

Fireproof brick 15 is placed into the box. Mechanical clamps 16 are attached to the suspender cantilever through ribbed insulators.

See page 136

Fig. 67. Scheme of the automat AE - 5.

Negative DC terminal is connected to a copper busbar 17, which is in turn connected through an insulating washer to the body of the drive. The current is conducted away by brushes 18 which are connected to flexible copper foil packs 19 and conduct the current to the clamps of the suspenders.

Since the present construction of the automat allows for the possibility of heating of long rods (1.5 - 2 m), the suspender is lengthened to a considerable degree and contains in its upper part a cantilever with a permament magnet as an additional device for clamping the heated details.

As a result of rotation of the drum the suspender is displaced up and down by means of a template 20, attached to the body of the drive and the roller 21, located on the suspender cantilever.

The template is mounted in such a manner that the suspenders are lowered when over the location of the bath, move in the lowered position along the sector, corresponding to the length of the bath and are then raised up.

The drive of the installation, as was pointed out before, is contained in the body 22, which fits on the end of the hollow axle 9.

The drive consists of a 0.25 - 0.5 kw electrical motor, reduction gears, and a system of pinions which permit the changing of the drum speed of rotation from 1 to 1.5 RPM.

A knock-off, which permits the throwing off of heated details during the rotation of the drum, is attached to shaft 9.

The operations of the automat can be summarized as follows:

In the front of the automat (the part of the automat opposite to the bath) the installation of the details to be heated into the suspenders is conducted.

See page 139

Fig. 68. Exterior view of the automat AE - 5.

During the rotation of the drum the suspenders, up to the position of the bath, are located at a height which permits them to clear the

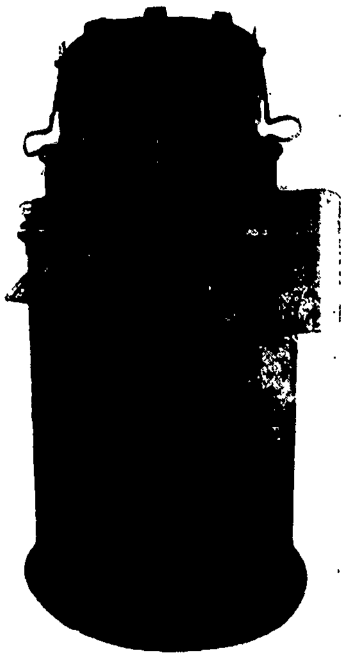


Fig. 68. Exterior view of the automat AE - 5.

walls of the bath with a gap of 1 - 3 mm. During rotation of the drum, subject to the action of the template, the suspenders are lowered into the electrolyte to a predetermined depth and continue to be dislaced, while immersed into the electrolyte. The details are heated while immersed into the electrolyte. At the end of the heating cycle, the suspenders, acted upon by the template, are raised up out of the zone of the bath carrying with them the heated details. Then follows the throwing off, or removal of the details, or blanks.

In this manner, the work of the operator of the machine consists only of the installation of the details to be heated into the automat.

Within certain limits, the depth of immersion of the details into the electrolyte and, consequently the length of the heated end, can be regulated in the automat.

Heating temperature, as was stated before, can be regulated by the duration of heating.

For the given construction of the automat this is achieved by altering the speed of rotation of the drum.

The automats of the described construction are being manufactured at the ATZ and are employed for heating of blanks in drop forging. A power of 165 kw from the generator is applied to the installations, which,

according to our estimates, will allow the heating of blanks with a heated surface area of up to 100 - 150 cm^2.

AUTOMAT OF THE TYPE AE - 6.

Automat of the type AE - 6 is designed for end heating of details with small dimensions with a heated surface area of 2 - 3 cm^2. This type differs by the fact that the current is supplied to it from a vacuum tube, or a copper-oxide rectifier.

See page 142

Fig. 69. Exterior view of the automat AE - 6.

As can be seen from Fig. 69, the mechanism of the automat is installed on a benchboard to which also a rectifier, a trigger and a signal armature are mounted. As far as the construction of the mechanism is concerned, it is analogous to the construction of the automat AE - 5 and differs from it mainly in size. In its overall dimensions it is approximately five times as small as the automat of the AE - 5 type and can be considered a portable installation.

This automat type can be effectively used in the instrument industry.

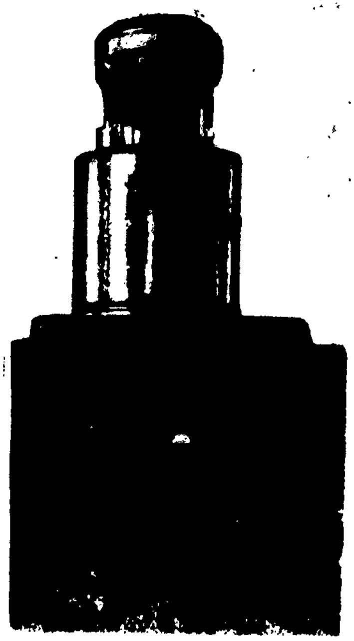


Fig. 69. Exterior view of the automat AE - 6.

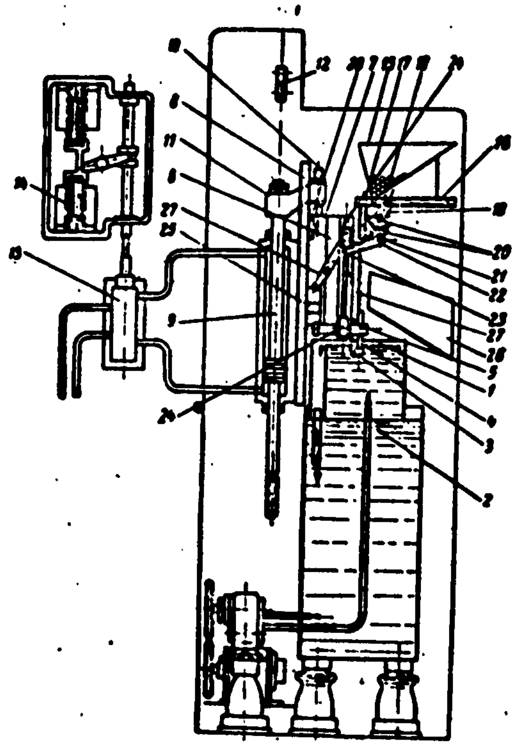


Fig. 70. Scheme of the automat AE - 7.

AUTOMAT OF THE TYPE AE - 7

Automat of the type AE - 7 is designed for end heating of blanks with a diameter of up to 20 mm. In this automat all the processes are automated, including the installation and the removal of the blanks.

See page 142

Fig. 70. Scheme of the automat AE - 7.

Fig. 70 shows the scheme of the automat. Here the electrolyte bath 1, supply tank 2 and the remainder of the circulating system have the same relative layout and construction forms, as in the automat AE - 4.

The suspension of the automat, analogous to automats of the type AE - 4 and AE - 5, has a metal box 3 with a brick 4 and mechanical clamps 5, by their form resembling to pincers, mounted into it. This is required for the installation and clamping of the details to be heated.

Unlike previous constructions the displacement of the suspension in this automat is achieved with the aid of a hydraulic cylinder. The suspension is attached to the support 7 through a textolite plate 6; the former can move along the guides of the plate 8. Support 7 is connected with the hydraulic cylinder (-piston rod) 9 by means of a regulating

screw 10 and a sleeve 11. Regulating screw 10 permits one to change the lower position of the suspension and, consequently, the depth of immersion of the details into the electrolyte.

The range of the cylinder piston rod travel is regulated by thrust screws 12.

Cylinder piston rod 9, as is the usual case in hydraulic systems, is put into motion with the aid of a hydraulic pump. The changing of the cylinder piston speed and its working regime are achieved with the aid of panel 13, interlocked with an electromagnetic switch 14, acting from the time relay. Thus the basic units of electrical control of the automat are the time relay and the electromagnetic switch.

The blanks are placed into a bunker 15 and one by one fall into the slit of the bunker slider 16. When the slider 16 reaches its extreme leftmost position the blank falls into the bunker groove 17; with this it assumes a vertical position and falls onto the brick of the suspension 4 into the jaws of the suspension clamps 5.

The displacement of the bunker slider takes place in the following manner.

A roller is placed on the bunker slider 16; the roller fits into the groove of the fork 18. The fork fits on the axle 19 on which a gear

20 is also attached; this gear interlocks with another gear 20, attached to the axle 21. Lever 22 is located on the same axle and carries at its end a textolite roller 23. During the displacements of the suspension, regulated supports 24 force the bunker slider to move by pressing down on the roller of lever 22.

After the blank falls into the suspension clamp the working cycle of the automat is started. The support, carrying the suspension, is displaced downward: meanwhile the jaws of the clamp are brought together and clamp the blank. At the very lowest position of the support the blanks are immersed into the electrolyte to a required and set depth and are subjected to heating.

As was pointed out before, the duration of heating of blanks, i.e., the time interval that the support is in its lowest position, is set by the time relay.

After the time relay opens and the electromagnetic switch, acting on the valve system of the panel, switches over the direction of motion of the cylinder piston, the support and also the suspension are displaced upwards. With this the jaws of the clamp are opened with the aid of a fixed cam 25. At that moment the heated part is ejected from the automat along the groove 26, with the aid of a lever system 27, acting from the

fixed cam 28. The support of the suspension 24 in this moment, pressing down on the roller 23, sets the bunker slider 16 in motion and the following blank falls into the jaws of the suspension. Thereafter the working cycle of the automat is repeated.

The productivity of the automat of the type AE - 7, like the type AE - 4 can be increased by the installation of a large number of clamps on the suspension.

AUTOMAT OF THE TYPE AE - 8

Automat of the type AE - 8 is the first installation based on the principle of sequential heating in an electrolyte and is designed for solid, or surface heating of blanks and details.

See page 147

Fig. 71. The scheme of automat AE - 8

Fig. 71 shows the scheme of the automat and Fig. 72 - its general view. Here the electrolyte bath 1 is connected with the tank 2 and the piping network which ~~XXXXXXXXXXX XXXXXXXXXXXXXXXXXX~~ create the circulation of the electrolyte and keep its temperature and level at const-

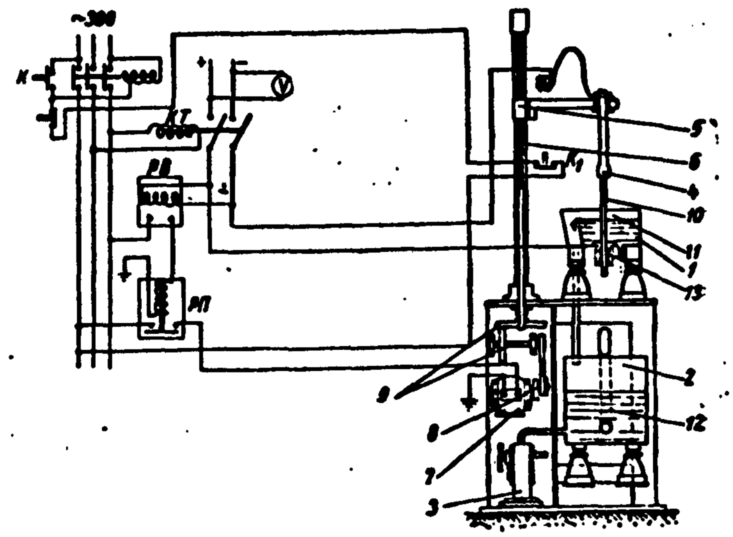


Fig. 71. The scheme of automat AE - 8

ant values.

Clamps 4 for the details are attached on the traverse 5 which can be displaced up or down by means of the screw 6. The clamps are insulated from the traverse by means of a gitenax washer and are connected to the negative DC source terminal by way of a flexible pack of copper foil. The positive terminal is connected to the bath.

Rotation of the screw 6 is achieved by means of an electrical motor 7 through a reducing gear 8 and friction discs 9. This drive method permits one to change the speed of motion of the traverse and , consequently that of the heated detail.

The detail to be heated 10, fastened into the clamp 4, is installed in relation to the bushing 11 depending upon the required heating conditions. Thus, for example, for the case where it is necessary to heat the whole detail the free end of the detail is placed at the beginning of the bushing opening. In this case, after the entire detail has passed through the bushing, i.e., after conclusion of the heating, the clap 4 is automatically opened and detail 13 is ejected from the installation by way of groove 12. If it is necessary to perform local heating the detail is installed with respect to the bushing in a manner such that only the part of the detail to be heated would pass through the

electrolyte. It should be pointed out that this method permits one to obtain a strictly limited heating zone.

See page 150

Fig. 72. General view of the automat AE - 8.

The operations of the installation can be summarized as follows:

After fixing the details in the clamps the operator presses the pushbutton K. When the button K is pressed DC current is switched on by means of the contactor KT, and heating is started. With this the time relay TR is also switched on. At the end of a certain period of time (3 - 5 sec), which is necessary for the obtaining of a stable heating effect of the cathode (detail), the time relay, by way of an intermediate relay IR, disconnects the electric motor which moves the traverse, carrying the heated details.

After the heating has been completed the detail is automatically ejected; also automatically, by means of an end disconnector K, the electric motor is turned off. Then follows the raising of the traverse and the attachment of new details.

Heating of blanks for hot mechanical treatment and surface temper-

ing of track pins, rocker arm rollers and a number of other details can be achieved on the described installation.

AUTOMAT OF THE TYPE AE - 9.

Automat of the type AE - 9 is designed for the sequential surface tempering of tractor caterpillar link pins.

The construction of this automat can be seen in Figs. 73 - 77.

In the design of the automat the previously described principle of a sliding contact device was used. In selecting this principle, which considerably simplifies the installation of the details into the automat, it was anticipated that it would be used for automatic loading of the details in the future.

The construction of the mechanism of the automat for sequential displacement of heated details is based on its continuous operation. In the heating of the details in one move, i.e., during the sequential displacement of the details downward, the mechanism of continuous operation leads to a blank reverse move. In connection with this, in order to increase efficiency, the automat is multipositioned. It has twelve installation positions which are broken up into three groups. Each group is displaced with respect to the others by 1/3 of XXXXXXXXXXX the travel. In

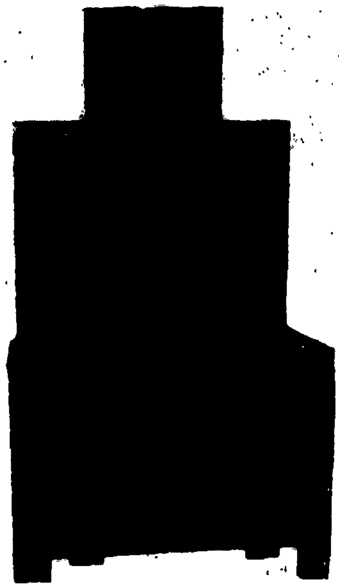


Fig. 72. General view of the automat AE-8.

this manner in the automat a simultaneous and continuous heating and tempering of four details takes place.

By referring to the previously stated condition of the unpracticability of increasing production with an increase in power, i.e., due to the increase in the electrolyte layer depth in the bath, the discussed automat construction is designed for a mean electrolyte layer depth in the bath of 20 - 25 mm. This determines the productivity of one automat at 120 - 150 details per hour when the power is 60 kw.

As can be seen from Fig. 73 the automat body, assembled from channels, contains in its lower part a supply tank 1, the electrolyte bath 2 and the pump 3 with the piping network which form the circulating system of the installation.

See page 152

Fig. 73. Automat AE - 9

See page 153

Fig. 74. Automat AE - 9

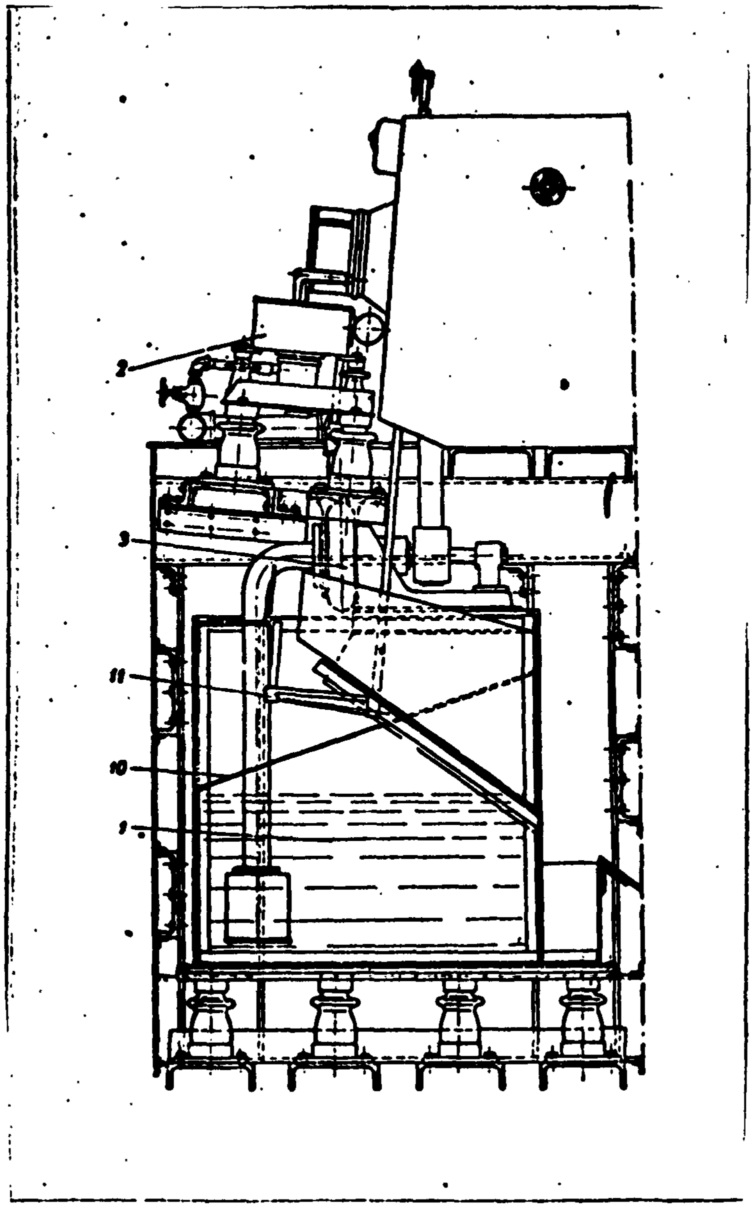


Fig. 73. Automat AE - 9

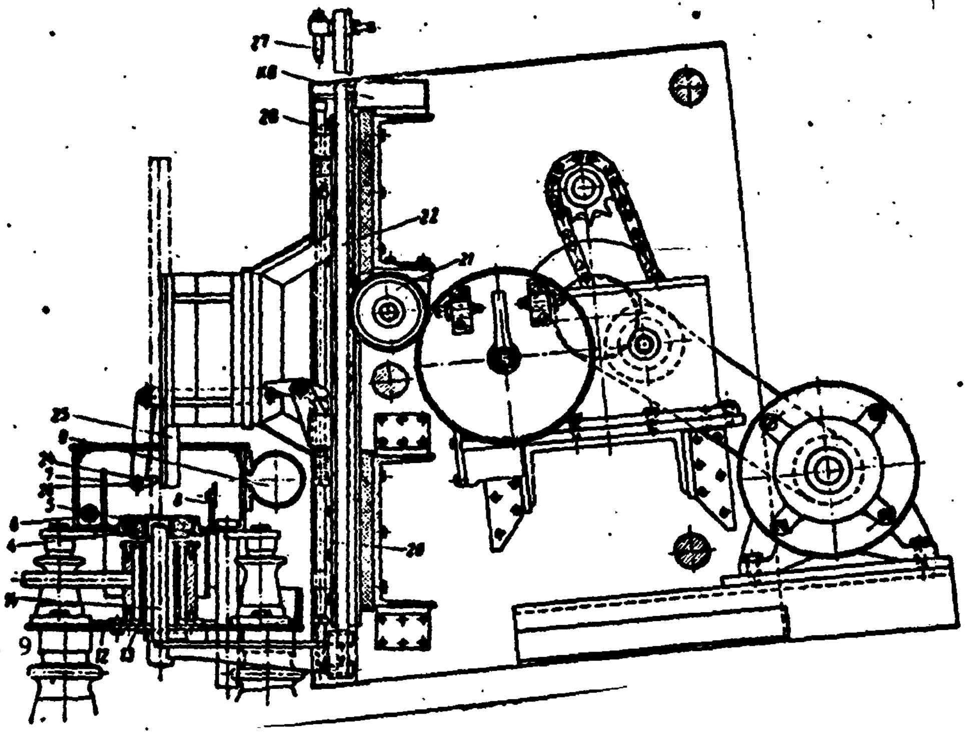


Fig. 74.
Automat AE - 9

See page 155

Fig. 75. Automat AE - 9.

Bath 2 has all the elements which were indicated in the discussion of the basic scheme, namely: openings for the installation of shields are made in the bath bottom corresponding to the quantity of the installation positions. The shields 4 (see Fig. 74) are mounted in clips 5, which are attached to corresponding openings of the bath. The electrolyte

See page 156

Fig. 76. Automat AE - 9.

is fed into the bath through a pipe 6 which has several openings. The interior wall of the bath 7 makes the supply of electrolyte uniform. The height of the second interior wall 8 can be regulated, thereby establishing the necessary depth of the electrolyte layer; excess electrolyte flows over this wall.

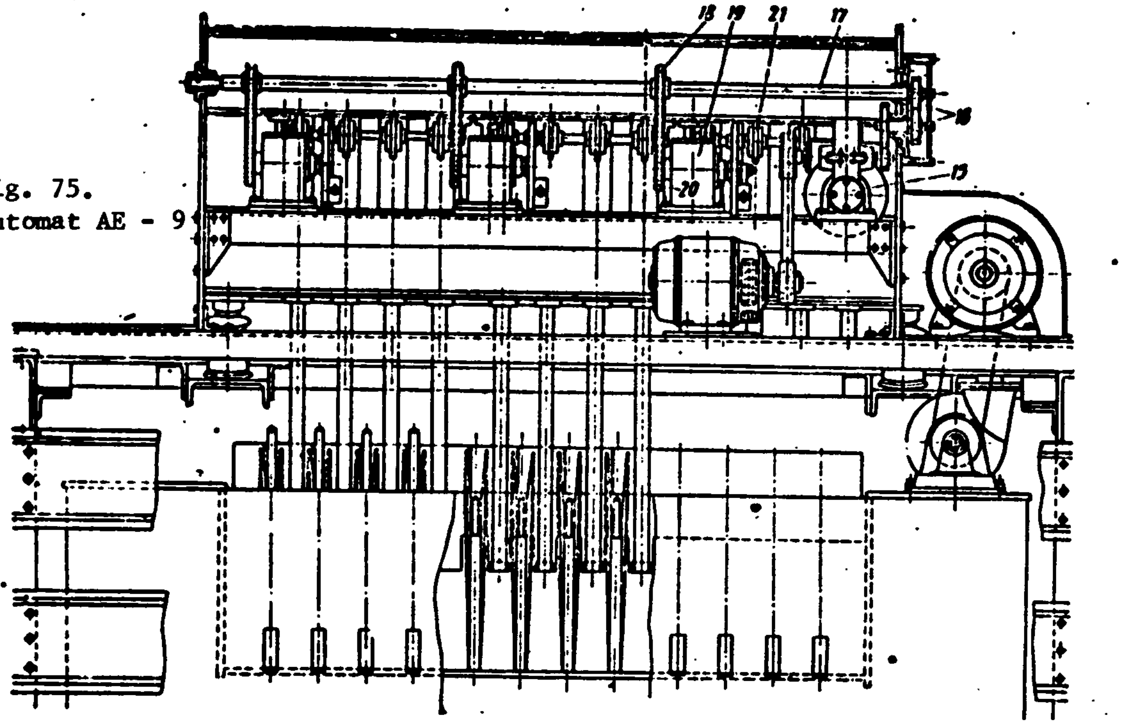


Fig. 75.
Automat AE - 9

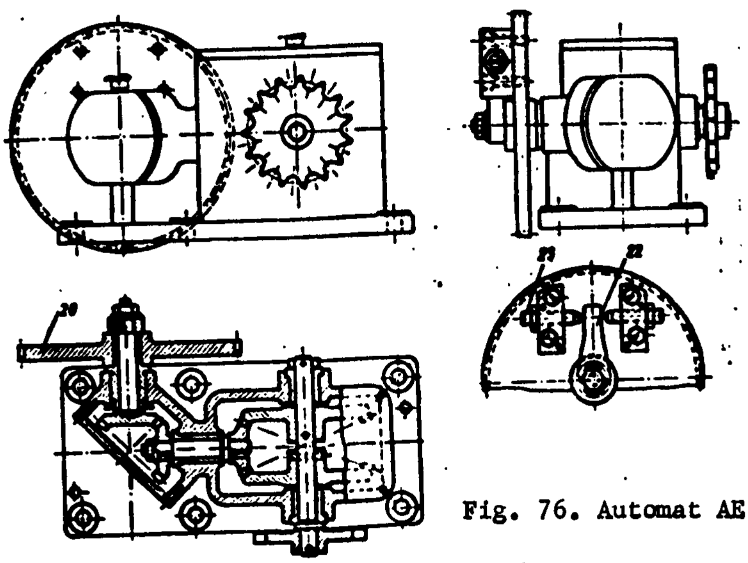


Fig. 76. Automat AE - 9

Vent pipe 9, which serves to remove electrolyte vapors, is attached to the rear wall of the bath.

The distinguishing characteristic of the construction of the supply tank 1 is that it is closed up on the top with a cover 10 (Fig. 73), which has a number of openings for the electrolyte passage and a plate with grooves 11 (Fig. 73), which are there for the purpose of ejecting details from the automat after their tempering (see also Fig. 75). Such a tank construction favors the cooling of the electrolyte and protects the mechanism of the automat from the action of the vapors.

Between two rows of supporting insulators underneath bath 2, the plate 12 is attached on which shower devices 13, for tempering of heated details, are mounted. Shower devices are connected to the common electrolyte circulating system. Here it should be pointed out that the capacity of the pump of the circulating system must be 250 - 300 liters per minute.

See page 158

Fig. 77. Basic electrical scheme of the automat AE - 9:

2M - o.5 kw, 300 RPM electric motor; 1M - 3 kw, 1500 RPM electric motor

тролита, здесь следует указать, что насос циркуляционной

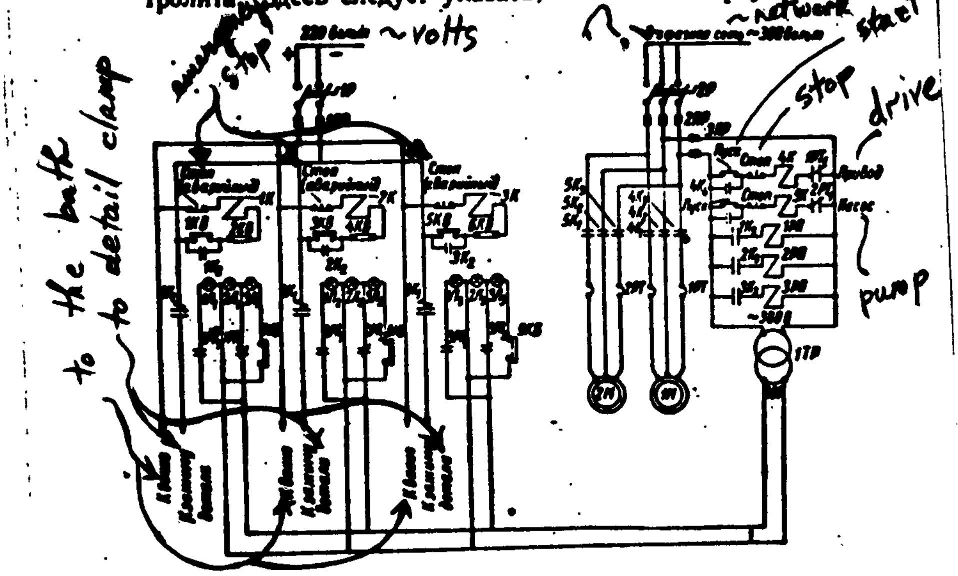


Figure 77

4K - 5K - magnetic starters; 1л - 3л - signal lamps; 1 IR - 3 IR - intermediate relays; 1 ed - 9 ed - end disconnectors; 2S - switch 25а; 1 S - switch 400а; 1 - 3 PR - protectors.

The insulation of the electrolyte bath and all the connected units and details of the circulating system from the body of the supply tank, is achieved by having the former sit on support insulators.

The automat mechanism is contained in the upper part of the body.

As was stated previously, the automat mechanism creates a uniform reciprocating motion of the coupling rods 14 (Fig. 74) which displace the heated details through the bath 2. Here a twin reducing gear 15 (see Fig. 75.) by means of interchangable pinions 16 puts the shaft 17 into rotating motion. Star wheels 18, fitted onto the shaft 17, through plastic chains set the mechanism of the reversible drive of the sliders 19 into motion . There are three such reversing mechanisms corresponding to the number of groups of installation positions.

The reversing mechanisms, through pinions 20, (Fig. 75 and 76) are connected to slider drive. Each slider drive has four leading pinions 21 (Fig. 75) which are connected with the slider racks 22.

The pinion of the reverse mechanism drive 20 is designed in a man-

ner that during one full revolution it displaces the slider racks for a distance of 560 mm, i.e.the distance equal to the length of the heated detail and the length of the shower device. In the course of such a travel, the detail to be heated, while being installed on the supporting piston 14 in its uppermost position, during the lowering of the sliders and, consequently the supporting pistons, into its very lowest position, can be automatically ejected from the automat.

One version of the setup of the reverse drive mechanism of the sliders can be seen in Fig. 76. Here two conical pinions, with part of the teeth removed, are fitted on one shaft. These pinions are interlocked with a third conical pinion. The relative location of the teeth on the first two pinions is such that the third pinion alternately interlocks with each achieving reversibility. Accurate work of such a mechanism of reversing is achieved by balancing the sliders with the aid of counterweights attached to pinion 20.

Reversal mechanism shown in Fig. 76, was also used in another version where one of the two conical pinions with removed teeth is eliminated. In that case the slider counterweight must be increased and the reverse motion is conducted at a great speed under the action of a counterweight.

It should be pointed out that the insulation of the supporting pistons 14 from the body is achieved by mounting slider guides on textolite plates. With this the leading pinions 21 (Fig. 75), connected to the sliders, are also insulated by having their hubs made of textolite.

In discussing the automat of the type AE - 8 it was pointed out that in order to obtain a stable heating effect, during the first moment, before the beginning of displacement of the part to be heated it is necessary to conduct a short delay. This was accomplished by switching on of the electric motor of the automat through a time relay.

In the automat of the type AE - 9 such a delay in the first version can be achieved by the following reversal mechanism design. The pinion of this mechanism 20 is not fixed on its axis and is set into rotation by the cam 22 through the thrust screws 23 attached to the cam. By regulating the clearance between the cam and the supporting screws the necessary stop duration of the sliders can be obtained. In the second version of the reversal mechanism, when the slider stays in its upper position for a longer period of time, the stop is achieved by the installation of templates on the pinions 20, which switch on the current by means of end disconnectors a few seconds before the beginning of slider motion.

The details to be heated are installed in the automat on the supporting cams 24 and prisms 25 (see Fig. 74). Supporting cams 24,

by means of acoupling rod 26 and a system of levers, step back automatically when the sliders approach their uppermost position and the details, sliding along prism 25 are installed on the supporting pistons 14.

As can be seen from Fig. 77, showing the electrical scheme of the automat, the negative pole of the DC source is attached separately to the detail clamps (prisms 25) of each installation position group. By means of end disconnectors ED (see Fig. 77), the current , in any given area of slider travel, can be turned on or off through the contactors with the aid of coupling rods 27 and 28 (see Fig. 74).

The described layout of the automat determines the following order of its operations.

The switching on of the automat is accomplished by turning on of the DC switch shield, the turning on of the electrical motors for the pump and the reducing gear.

The operator must only feed the details to be heated into the automat. When any of the slider groups approaches its uppermost position, the supporting cams are removed and the details are automatically installed onto the supporting pistons. Simultaneously with this the contactor is switched on and the heating process is started.

After a certain time d lay, determined by the operation of the me-

chanism, the displacement of the details and their sequential heating is begun. After emerging from the bath zone the heated details are subjected to tempering in the following zone of the sprayers. The current is automatically disconnected, determined by the speed of the detail displacement motion, when the heating of the necessary area length is completed.

As has already been pointed out, the track pin is heated for a distance of 390 mm and the unheated parts are the ends which remain unheated for a distance of 20 mm. In the extreme low position of the sliders the details emerge from the zone of the sprayers and are ejected from the automat.

Regarding the period of the possible installation of the details into the automat one can judge from the position of the sliders, the supporting cams and also from the burning of the signal lamps. The lamp 1L (see Fig. 77) lights up when the DC is switched on and during this period the installation of the details is dangerous. When the DC is switched on lamp 1L is turned off and lamp 2L is lit.

Lamp 3L lights up shortly before the moment of switching on of the DC and signals that period of possible loading is over.

In each cycle the loading period of the details is 3 minutes.

It should be pointed out that during continuous operations of the

automat the possibility of overheating of the electrolyte arises. In connection with this an electrolyte reservoir tank is furnished which is connected with the basic supply tank of the automat. The reservoir tank must contain a cooling system.

During the manufacturing of the automat of the type AE - 9 at the Altai tractor plant, named after M. I. Kalinin, based upon subsequent studies of its operation, the following basic construction changes were introduced.

Because the details in their original condition had a certain degree of warping, their sliding on the prisms did not establish the necessary contact. This forced us to abandon the principle of the sliding contacts and to attach the negative pole to movable spports, on which the details during the heating process remain stationary. In this case the prism acts only as a guide for the details.

The second construction change consisted of the mounting of the shower device on separate and not a common plate, since in the latter case this would have led to current leakages.

CHAPTER IV

AREAS OF APPLICATION OF ELECTROHEATING IN AN ELECTROLYTE

1. PECULIARITIES AND ADVANTAGES OF HEATING IN AN ELECTROLYTE FOR THERMAL TREATMENT

Great achievements by present day metallography have led to the development and the creation of new and complicated alloys and new technological processes, which have played a progressive role in the development of machine construction. For the realization of many processes and, particularly in their application to complicated alloys, methods of heating are subjected to many different requirements. Thus, for example, a number of processes requires a very high speed of heating. The method of surface tempering of details, made of carbon steel, is based upon the use of high speeds of heating. High speeds of heating are applied in a number of cases of heating for the purpose of forging and stamping of carbon steels, during welding processes, etc. On the other hand, however, during the thermal processing of details, made of alloys and details having complicated forms and nonuniform sections, high heating speeds are undesirable. A lowered thermal conductivity of many alloys in a definite temperature range negates the application of high speeds of heating for blacksmith production. High heating speeds, in these cases lead to high stresses in the details and to their des-

truction.

Most of the processes of thermal treatment, like tempering, drawing, refining, annealing which require definite structural changes, require heating at a definite speed in a given temperature interval and strictly fixed exposure.

The selection of particular heating regimes is often dictated by the conditions of deformation and warping of the details.

The creation of special heating media is necessary for the achieving of isothermal processes of tempering, annealing etc. Many of the present day technological processes are built upon the application of heating in a neutral or reducing medium.

The application of a reducing medium in the heating of blanks for blachsmith work, permits one to use accurate methods of stamping, thereby sharply simplifying the technology of manufacturing of the machine details and bringing about an economy in the metal. The heating in a reducing medium, during thermal processing, also simplifies and reduces the cost of the technology of manufacture of the details and, furthermore, improves their quality. Heating in a reducing medium is imperative for many processes of soldering, clinkering of alloys, etc.

Finally, one can point to such significant requirements of

heating methods, like economy, high productivity, safety and better working conditions for labor.

From all this it can be understood that the evaluation of this, or that method of heating of metals will be based on to what degree it will satisfy the above requirements.

Present day methods of electroheating of metals have a number of advantages, peculiarities and limitations. From our point of view, one of the problems for scientists, working for research institutes, and engineering and technical personnel of companies, is the objective study of the peculiarities of each method of heating and the determination of more useful areas of its application. Correct determination of the more useful area of application of new methods of electroheating will favor a most rapid and wide implantation of this method in industry.

From the presented data, dealing with the application of the method of heating of metals in an electrolyte for the purpose of thermal treatment and hot mechanical processing, it becomes evident that this method satisfies most of the requirements of present day technology. The possibility of regulation of the speed of heating in a wide range is innate to the method of heating in an electrolyte; this permits one

to achieve an accelerated, or decelerated, as well as a methodical process of heating.

Heating in an electrolyte can be used conducting isothermal processes. Great advantages of the electrolyte heating method appear in connection with fact that it is related with the reducing medium.

The possibility of easy achievement of automation of the process, the creation of highly productive units of a simple construction and a relatively high efficiency of the process help to make the method very economical.

The efficiency of automats for electrolytic heating,of utilization of DC power for cases of sequential surface tempering to a depth of 3 - 5 mm is 19 - 21 %, for sequential total heating - 28%, and for end heating - 25 %. In some of our experimental cases the efficiency of the method exceeded 30 %.

See page 169

Fig. 78. Distribution of losses in the installation for heating with high frequency currents with machine and tube oscillators. (Vologdin).

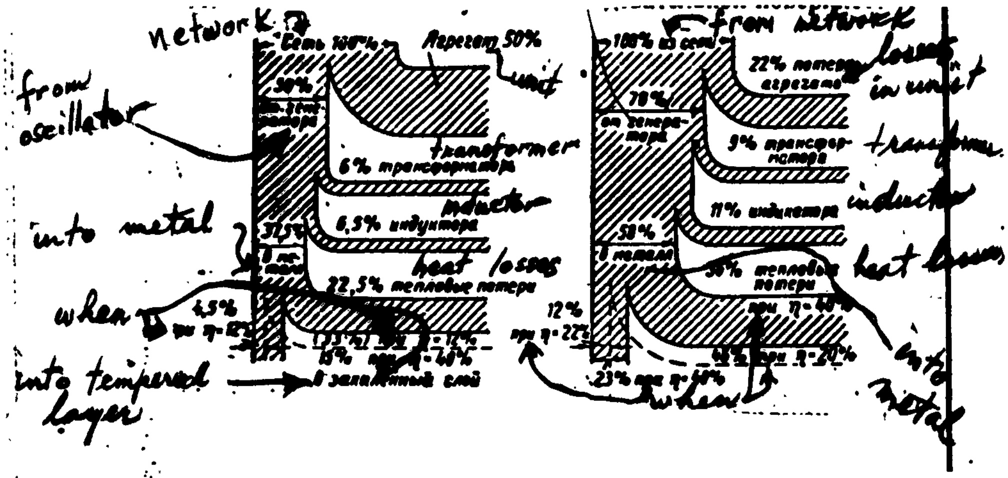


Fig. 78.

In electrolytic heating automats, the losses of the current, taken from the network, when changed into DC are 5%, consequently, the stated values of the efficiency, in relation to the current taken from the network, are lowered only by 1 - 1.5%. Thus the basic losses for electrolytic heating consist of heat losses.

Fig. 78, from the data received from professor Vologdin, shows a graph which gives one a picture as to how the losses are distributed in the individual parts of machine and tube high frequency installations and regarding the efficiencies of these installations.

As can be seen from Fig. 78 in the balance sheet of losses of high frequency installations an important place is occupied by losses related to the regeneration of current; these are particularly high for tube installations. Even in the comparison with the generalized data, obtained from professor Volgdin, the efficiencies of electrolytic installations are more rational than those obtained from high frequency heating.

Here it should be pointed out in addition, the data, on the basis of which the efficieencies of the electrolyte installations were computed, was obtained without sufficient consideration of factors which would tend to raise the efficiency and which are based on research dealing

with the nature of the heating effect.

Taking advantage of the possibilities of intensifying the heating process in an electrolyte will bring about a significant increase in its efficiency.

Here we do not propose to discuss all other economic indecies, like, for example, the cost of amortizing and repairs of the installations, costs of operation, etc. It can be stated that all these indecies put the electrolytic heating installations into a favorable light, since they are characterized by a relatively low cost, simplicity of the installation and the simplicity of maintenance.

Our works are far from having included all areas of possible application of electrolytic heating for the purposes of thermal and hot mechanical treatment of metals. It can be stated, however, that the research, intensively conducted by scientific research organizations and companies, related to the development and installation of methods of heating of metals in an electrolyte, will, in the near future, lead to wider applications of this method.

Works that show perspective in this field are those dealing with high productive capacity automated units for the performance of various processes, related to heating of metals and works treating the use of

physical-chemical processes, occurring during this method of heating.

Given below is the information regarding research we have conducted and treated above.

2. THE SOLDERING ON OF CONTACTS OF A MAGNETO BY MEANS OF ELECTROHEATING IN AN ELECTROLYTE.

The manufacturing of contact screws of a magneto by the Altai automobile-tractor electrical equipment plant was handicapped by the process of soldering on of tungsten contacts. For this process in similar plants, special ovens with hydrogen atmosphere are employed; however the AATEEP (Altai plant) lacked these ovens.

From experience with similar plants it is known that the hydrogen installations, used for this process are dangerous as far as explosions are concerned, complicated to maintain and consume great quantities of ammonia.

The soldering on of contacts due to these circustances creates great difficulties.

In solving the problem of selecting and developing a process for the soldering on of contacts for a magneto for the AATEEP we were looking for a process which could be developed in a short period of time with-

out significant expenditures of money.

The process of soldering on of contact screws of a magneto has properties connected with their small size and must be distinguished by its high production.

It can be understood from here that the known methods of soldering, performed in oil ovens of various construcions with the aid of copper and borax, are not applicable for the given case.

The achieving of the process of soldering with copper solder in a reducing medium will most easily solve the difficulties inherent to the stated properties.

Our works dealing with electroheating in an electrolyte allowed for the possibility of using this method of heating for the soldering on of magneto contacts, which, as was stated above, is connected with a reducing medium, can be easily regulated with respect to speed and temperature of heating, is quite productive and can be easily achieved in practice.

The basis of the original version of the developed process of soldering-on was the method of end electroheating in an electrolyte with a shielded end cross-sectional area; in the following version - the method of local heating with a shielded fixed contact.

The selection of these methods was dictated by the possibility of

accomplishing the basic requirements of the process -,the reliability of fixing the components of the detail, namely, the screw, soldering plate and the tungsten plate.

The devices which we developed for achieving the process of soldering -on of contacts serve as the suspension for the automat of the type AE - 4.

Fig. 79 shows the device built on the principle of end heating with insulated end cross-sectional area.

The screws 1 to be soldered on are placed into end cross-section openings of the holders 2 which are located in the body 3. The holders, by means of springs 4, press the details to be soldered against the insulator 5, or the installation plate 6, attached to the body 3 through a textolite plate 7 and struts.8. The installation plate 6 has openings which locate the heads of the screws to be soldered on. These openings at the same time also serve as nests for the installation of copper and tungsten plates.

Insulator 5, made of fireproof brick, is held in place by means of clips 9 and can be easily installaed and removed.

In order to install the details into the device it is necessary to sink the holders into the body which is accomplished by pressing by hand the beam 10. This position of the holders can be fixed by the fixer 11.

The scheme of installation of the details for soldering in this de-

vice is shown in the same Fig. 79.

See page 176

Fig. 79. The device for soldering on of contacts

The first operation consists of the installation of the screws into the holders, for the purpose of which the latter are sunk into the body and clamped by the fixers 11. Here the device is placed with the installation plate facing upward and the insulator 5 is removed.

In the second operation the fixer 11 is removed as a result of which the holders, which press the screws against the installation plate, are freed. The cylindrical protrusions which are on the head of the screw, fit into the openings of the installation plate.

In its thickness the installation plate is 2 - 3 mm larger than the cylindrical protrusions on the screw head are high; thus the screws, when pressed against the installation plate form nests at the openings in the latter which are convenient for the installation copper and tungsten plates. The latter are loaded into the nests by means of forceps.

In the third operation the holders with assembled details of the con-

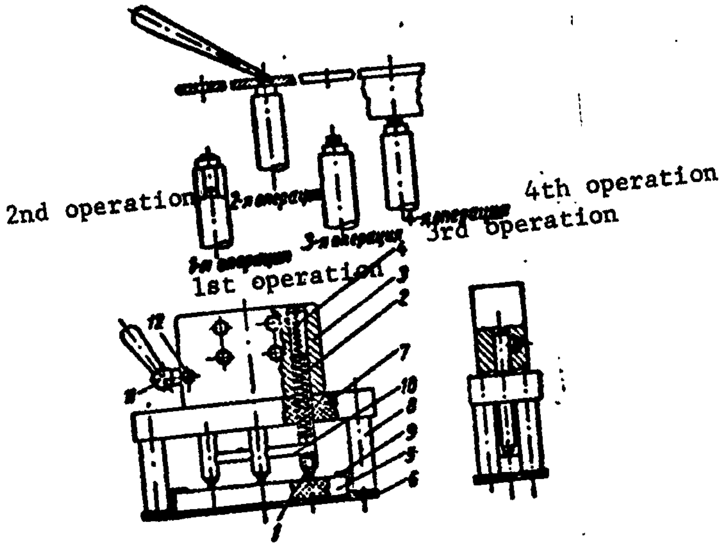


Fig. 79. The device for soldering on of contacts

tact screws are thrown below for the installation of the insulators. Finally the fourth operation consists of the installation of an insulator to which the assembled details to be soldered are pressed against.

Fig. 80 shows the device for soldering which is built on the principle of the method of local heating with a shielded fixed cathode. Here insulator 1, made of fireproof brick, is fixed into the body of the device. Metal nests 2 are mounted into the insulator; the screws for soldering 3 are installed into these nests. Coupling rods 4 press the copper and tungsten plates against the heads of the screws. Bushings 5, which can be displaced along the coupling rods 4 and held in their upper part serve as the nests for the installation of copper and tungsten plates.

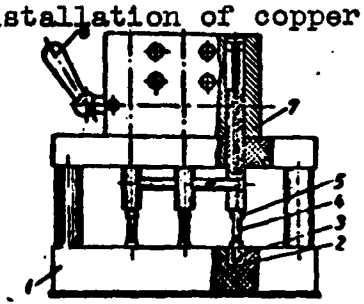


Fig. 80. Device for the soldering on of contacts.

The installation of the details for soldering is accomplished here in the following order.

The coupling rods are pressed up and fixed in that position by means of the fixer 6. The screws to be soldered are placed into the metal nests 2. The bushings 5 are lowered along the coupling rods onto the heads of the

screws and copper and tungsten plates, with the aid of forceps, are placed into their nests. Then with the aid of the springs 7 coupling rods are lowered and tightly press the copper and tungsten plates against the heads of the screws. The bushings 5 raise along the coupling rods after which the device is attached in the automat for heating. Heating for soldering of details in an automat is conducted in the same order as was previously described in the discussion of its construction.

From the presented description it can be easily seen that the second version of the device , as far as the conditions of preparation of the details for soldering-on is concerned, is more convenient for practical application. Aside from that, conducted experiments have shown that the process of soldering - on, based on the principle of local heating with a fixed and shielded cathode, yields the more stable and qualitative results.

Various versions of heating were tried by us in our experiments which were conducted for the purpose of determining optimum conditions for the soldering-on. The evaluation of the results of the soldering was conducted on the basis of character of the fused area and the following metallographical exploration of the soldered details.

Results of the conducted experiments have shown that the soldering is satisfactorily achieved during the following regime: voltage 180 -

200 volts, current - 6 - 8 amperes and the duration of heating - 8 sec.

It should be pointed out that the device is immersed into electrolyte in such a manner that the height of the electrolyte level above the head of the screw was 4 - 6 mm.

A comparison between the soldering achieved through electroheating in an electrolyte and the contacts soldered on in hydrogen ovens was conducted in the metallographical research.

The soldering XXXXXXXXXX conducted by us is characterized by the presence of a uniform layer of copper with a thickness of 0.1 - 0.3 mm at the seam between the tungsten plate and the screw; oxides in the layer of solder are almost entirelly absent.

The details soldered in the hydrogen oven showed that the layer of copper at the joint was characterized by the nonuniformity of its thickness (its thickness varied in the limits of 0.1 - 0.8 mm), and in one of the two studied cases it was entirelly lacing at the seam.

For comparative evaluation of the process we have developed and the existing process used by plants manufacturing magnetos, as far as the productive capacity and working conditions are concerned, in addition to what has already been stated about the process of soldering in hydrogen ovens, one should add the following related conditions associat-

ed with the latter. The loading of the details, *for* soldering in hydrogen ovens, is conducted into special graphite plates. Screws and then copper and tungsten plates are placed with forceps into the nests of these plates.

The plates with the contact screws, the details of which have been assembled in this manner, are loaded into the oven and heated in accordance with a predetermined regime the duration of which is of the order of several hours.

Experience with electroheating in an electrolyte has shown that this method, in comparison with the method of soldering in hydrogen ovens, can possess significant advantages over the latter not only the working conditions, safety and quality, but also in productivity.

As was already pointed out, the duration of heating required by the new heating process of soldering of magneto contacts is 8 seconds. A considerable quantity of details can be heated simultaneously. By installing the details simultaneously in several devices which guarantee continuous operations of the automat, a very high rate of production can be achieved.

Aside from this the proposed method of soldering is distinguished by its advanceness, does not require complicated equipment and can be

easily installed at a short notice.

3 FUSION AND HOT PRESSING WITH HEATING IN AN ELECTROLYTE

From the description of the method we have developed for the soldering on of contacts it can be easily seen that the design of devices, permitting the performing of the heating in an electrolyte under pressure, does not create any difficulties.

For obtaining of small pressures, devices for soldering on of . contacts, analogous to those described can be used. For obtaining of large pressures various presses can be utilized.

The use of pressure during heating in an electrolyte, related to a reducing medium and the possibility of obtaining of very high temperatures, allows the creation of entirelly new procedures for conducting such processes as fusion and hot pressing of alloys, melting processes, etc.

Here we shall shed light on only one of the methods which have been developed by us and applied at ATZ (Altai tractor plant?) - the manufacture of diamond pencils. Diamond pencils, as is known, permit the use of minute diamonds (diamond crumbs), which are wastes of production, for the filling of grinding stones.

The existing method of manufacture of the diamond pencils

consists of the following: tungsten powder, impregnated with a rubber glue is placed into the metal press forms. Diamond crumbs are buried at specified distances from each other between the layers of the powder. Then the powder is moulded with a press and the pencil obtained in this manner is subjected to drying at a temperature of 200°C. The next operation consists of placing of the pencils for a definite time period into a molten mixture of copper and aluminum.

The tungsten powder, fused together by the molten copper aluminum alloy provides a stable binder for the diamonds.

The method we have developed for the manufacture of diamond pencils carries out the process of fusion and pressing simultaneously.

A powderlike mixture of tungsten and copper is placed into a graphite press form. The placement of diamonds is conducted in the same manner as described previously. The assembled press form (Fig. 81) is clamped into a device, which in its construction is analogous to that used for soldering on of contacts. Here coupling rod 1 under the action of the spring 2, through plug 3 presses on the powderlike mixture, placed into the press form 4.

The device is installed into an automat of the type AE - 4 in which the press form is subjected to heating up to a temperature of 1050 -

1100°C. At this point the preparation of diamond pencils is concluded.

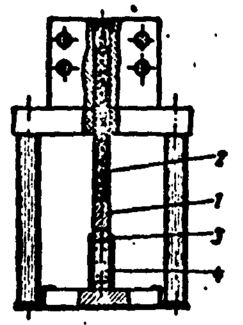


Fig. 81. The press form

Analogous to the process of manufacturing of diamond pencils as developed by us, the heating in an electrolyte can be used for fusion and hot pressing of alloys.

The application of such processes in the manufacture of hard alloys will significantly simplify the technology of their preparation. An improvement in quality of the fusion can be expected from the use of the process of hot pressing.

4. COMBINED UNIT FOR ELECTROHEATING AND STAMPING

The process of hot stamping of steel details, in the form used today does not permit one to use in full measure the highly plastic properties of the metal which it possesses at maximum possible temperature of its heating in the given process. This is caused by the fact that performing of the operations of heating and stamping separately leads to considerable heat losses in the transfer of blanks and their

installation in the stamps. Heat losses, during these operations are particularly high for details with small cross-sections.

It should further be pointed out that in many cases the imperfectness, in the sense of temperature and heating medium regulation, of the ovens used in blacksmith shops does not permit the heating of blanks for stamping to the upper limits of optimum temperatures for danger of strong oxidation and overheating.

The stamping of details at lower temperatures requires a press, or a hammer of a greater power.

When working for the creation of a combined unit, in which heating and stamping of blanks could be achieved simultaneously, our goal was not only the application of a more advanced method of heating for the hot mechanical treatment, but also the elimination of the heat losses which would permit the use of low power units of simple construction.

Primarily we were solving this problem for cross-breeding production, particularly for the upsetting of bolt heads.

The basis of the developed unit was the last method of heating in an electrolyte we discussed, namely, the end heating with shielded end cross-sections.

The sample scheme of a laboratory installation which we built, is

given in Fig. 82.

See page 185

Fig. 82. Laboratory unit for electroheating and stamping

Electrolyte bath 2 is mounted on table 1 and is connected through a pump with a supply tank, not shown in the diagram. In this manner the circulation of electrolyte in the bath is created; this is necessary for maintenance of a constant electrolyte level and temperature. A hexagon-shaped matrix 3 is attached to the bottom of the bath.

A case for the clamping of the blank is located above the matrix and is pressed into the body of the case 6 through a bronze bushing 4 and a textolite bushing 5. Case 6 rotates on journals 7 and cantilever lugs 8. Blank 9 is held in the case by means of a ball fixer 10. The thrust pin of case 11 is installed by the regulating screw 12. The position of the thrust pin is separately selected for each bolt size with a consideration such that the protrusion of the blank out of the case would exceed the value required for heating by 3 - 5 mm.

At the moment of the upsetting of the bolt the thrust pin 11, and consequently the blank 9, due to settlement of the spring 13, can move

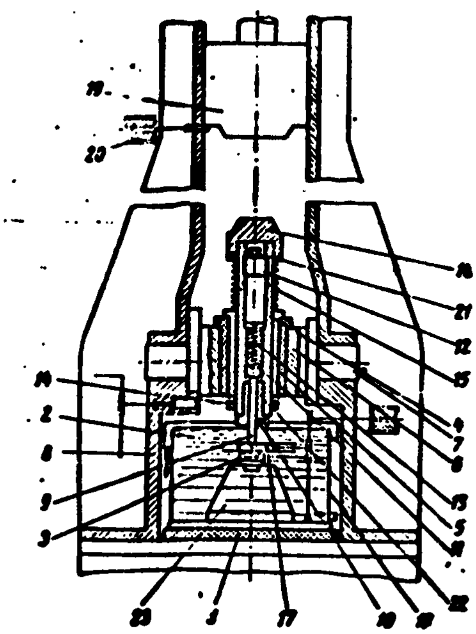


Fig. 82. Laboratory unit for electroheating and stamping.

upwards to a determined height. Such possibility of displacement of the stress pin permits,at the moment of upsetting of the bolt head, to reduce the protruding part of the blank to a value necessary for the formation of the head.

The case is contacted with the ring 14 to which the negative DC terminal is connected. Positive pole is connected to the bath. The case, in its upper part, contains a shck absorbing spring 15 and an extension 16.

A plate of fireproof brick 17, mounted into a frame serves to insulate the end cross-sectional area of the blank during its heating.

By means of a system of levers 18, connected with a solenoid, frame 17 is automatically removed at the end of the heating cycle. Load 19 is freely displaced along guiding cantilevers 10.

The raising of the load is accomplished by means of a mechanical drive, or the solenoid, not shown on the scheme.

In its upper position the load is held by means of a catch 20 connected with the solenoid.

The operations of the combined unit of electroheating and stamping consists of the following.

The blank is placed into the case of the unit. For convenience of installation and removal of blanks, the case may be rotated into a hori-

zontal position at the start on the journal bearings of its body.

Prior to the switching on of the current, the case with the blank and the frame with the brick plate assume a position shown in the diagram.

By pressing the starting pushbutton one turns on the heating current and the time relay. At the end of the heating cycle the time relay switches on the frame solenoid and the catch solenoid.

At the next moment the load falls onto the extension of the case which results in the upsetting of the bolt head. The DC is disconnected prior to the moment of contact between the blank and the matrix, due to the load disconnecting the end disconnector in its fall. Then follows the raising of the load and the removal of the stamped detail.

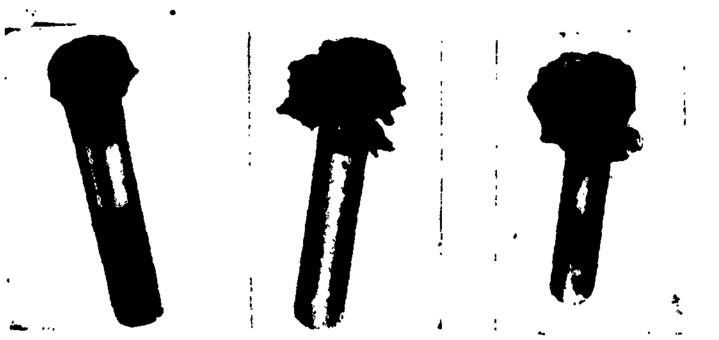
Experiments dealing with the upsetting of the M10 bolt heads were conducted on our laboratory installation. The blanks were heated for a length of 23 mm at a voltage of 240 - 250 volts and a time duration of 9 - 11 seconds.

The ,weight of the falling load was 18.5 kg and the height of the fall 500 mm.

Samples of stamped bolts are shown in Fig. 83a.

The presented characteristics of the power of the experimental installation and

the external view of the stamped bolts show that the process of stamping took place in the range of high plastic properties of the material.



a) b) c)

Fig. 83. Bolts stamped during heating in an electrolyte: a - normal form; b and c - forms of flaw

At definite heating regimes we obtained bolts with burrs having the shape of splashed metal (Fig. 83, b and c).

The displayed character of the burrs attests to the fact that during stamping the metal was in a semi-liquid state. This condition was reached due to a high temperature of the blank and the heating effect obtained from the deformation of the metal.

As far as the microstructure of the bolts we stamped is concerned it was in all cases characterized by its small grain structure.

On the basis of this experimental work we have already started the design of a production unit.

A combined unit for electroheating and stamping, in our opinion, can

be of considerable interest in the technology of hot mechanical treatment in the sense of increasing production and the "culture" of manufacture.

Work, for the creation of a combined unit for electroheating and stamping, is also conducted by us in the direction of using of the previously discussed method of heating employing a fixed shielded cathode. In that case the matrix of the stamp can serve as the shielded cathode. The use of this method will significantly simplify the construction of the unit.

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